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Water-based flexographic ink specifications and the effect they have on the ability to print within tolerance UPC symbols on single-wall corrugated board

Joseph Palmeri

WATER-BASED FLEXOGRAPHIC INK SPECIFICATIONS
AND THE EFFECT THEY HAVE ON THE ABILITY
TO PRINT WITHIN TOLERANCE
UPC SYMBOLS ON SINGLE-WALL
CORRUGATED BOARD

By

Joseph M. Palmeri

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ABSTRACT

THE EFFECT WATER-BASED FLEXOGRAPHIC INK STANDARDS HAVE ON UPC SYMBOLS PRINTED ON COMBINED CORRUGATED BOARD

By

Joseph M. Palmeri

The primary objective of this study was to determine the effect water-based flexographic ink specifications have on the overall print quality of Universal Product Code (UPC) Symbols. The study built on work done in 1980 by George Huddleston of the Mainville Forest Products Corporation. Selected for the study were two inks that closely resembled the ink specifications identified by Mr. Huddleston. The quantification of quality was made by printing UPC Symbols on single-wall corrugated board with the flexographic printing process, and observing the percentage of these symbols found to be printed within tolerance. These figures were then compared to the percentage of symbols found to be printed within tolerance using a flexographic ink not in accordance with Huddleston's specifications. The results of this study were determined to be inconclusive.

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INTRODUCTION

Originally, corrugated containers were used primarily to transport and protect products during shipment. The traditional type of printing on these boxes was known as spot printing. That is, the printing consisted of simple logos and part numbers located on one or several of the boxes' main panels. Viewers of the box would see a minimal use of color and graphics. Color quality was often poor and usually inconsistent. At the time, spot printing was commercially accepted because of the boxes' limited use and function. This allowed many of the larger integrated companies to adopt a high-volume, production-oriented philosophy, and to excuse poor print quality on the basis of commercial acceptance.[1] However, as the role of the container shifted away from the industrial consumer to the retail consumer,[2] and the function of the box moved towards advertising the product, the print quality of the finished box became increasingly important. This role was due to the growth of self-service department stores such as K-Mart, Sears, and J.C. Penney, as well as the demand created by

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[1] Roy LaFontaine, "Preprint: An Enormous Potential For Change," BOXBOARD CONTAINERS, September 1985, p. 19.

[2] Dick Parke, "Total Product Image: The fine art of retail packaging," BOXBOARD CONTAINERS, January 1986, p. 28.

these stores for point-of-purchase graphics on corrugated boxes to merchandize consumer goods.[3]

Prior to the advent of the self-service department store, a sales clerk was expected to provide all the necessary information about a particular product. This meant that most of a store's inventory remained in the back room until a sale was made. Self-service stores have gradually changed this. "... The store's entire inventory is now on the shelves, and with most of the employees working at the checkout area, there aren't many clerks to help you choose a product."[4] It is now up to the package to do what was once the job of the sales clerk. The product, and consequently the package, must now sell itself.

The past few years have seen the corrugated industry shift its focus away from spot printing and more towards the use of graphics as a sales tool in response to these demands. Graphics are now necessary, not only to make the carton more visually appealing, but also to help communicate a stronger selling message to the customer.[5]

Two statistics, prepared by C. Weston Beck and presented at the 1985 Flexographic Technical Association's annual convention, further emphasize the importance of graphics as a visual aid in the consumer's decision-making

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[3] Richard W. Porter, "Pioneer Advance Preprint," BOXBOARD CONTAINERS, June 1982, p. 27.

[4] Melissa Larson, "Retailers Want Self-Sell of Four-Color Cartons," Packaging, December 1985, p. 42.

[5] "Boxes That 'Tell Better' Sell Better," Packaging, February 1987, p. 53.

process. Beck states that, first, only 23% of all consumer purchases are preplanned, and, secondly, the average shopping trip is only thirteen minutes long.[6] Therefore, since very few items sell themselves on their own intrinsic value,[7] some type of attention getter is needed to help the consumer differentiate between many similar product lines. Alluring graphics act as the attention getters. "A colorful package transmits a message of implied intrinsic value."[8]

High quality graphics are the end result of five basic components: the press, the inks, the printing plates, the press crew, and the substrate.[9] All five of these factors must be optimum and based on continuing high standards in order to achieve a quality printing job. If any one of the five components are less than perfect, quality printing can only be marginally achieved, and even then, not on a consistent basis.[10] As more and more corrugated companies try to answer the need for more sophisticated graphics, the number of printing-related problems becomes even more apparent. Figure 1, page 4, is a summary of corrugated problems prepared by Eastman Kodak Company.

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[6] C. Weston Beck, "The Carton As A Sales Tool," 1985 Flexographic Technical Association's Annual Convention, p. 166.

[7] Dick Parke, "Total Product Image: The fine art of retail packaging," BOXBOARD CONTAINERS, January 1986, p. 28.

[8] Ibid., p. 28.

[9] G. H. Anthony, "Rubber Printing Plate Capability," Paper, Film & Foil Converter, October 1983, p. 100.

[10] Ibid., p. 100.

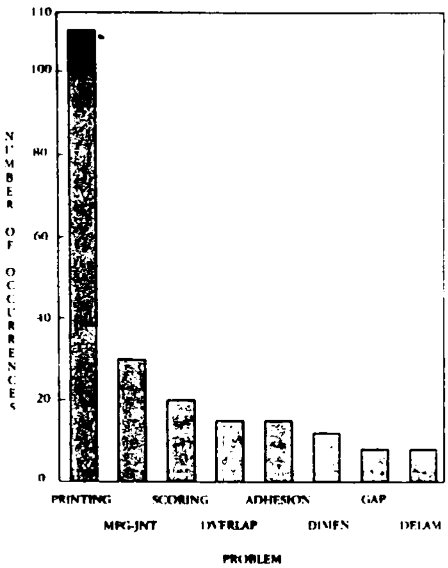

Figure 1 - Summary of Corrugated Problems[11]

It can be seen from the graph that the number of printing-related problems far outweighs the number of other problems generally associated with the corrugated industry.

The relationship between these five components and print quality is further illustrated by Robert Elfner, Vice President, Converter Consultant Group. In an article appearing in BOXBOARD CONTAINERS, October 1978, Elfner states that "a lack of clearly spelled out standards that must be met by the platemaker and ink people is the largest single cause of poor graphics and low productivity in a box

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[11] Douglas F. Metzger, "Statistical Quality Control And Just In Time," TAPPI Proceedings: 1985 Corrugated Containers Conference, p. 3.

plant."[12] Also expressing the need for standards, Douglas F. Metzger, Buyer for Eastman Kodak Company, explained at the 1985 TAPPI Corrugated Containers Conference that "... the first thing to be done when addressing product quality is to set up realistic specifications." Metzger goes on to say that "... realistic specifications, if adhered to, will result in a product that satisfactorily performs the function(s) for which it was designed."[13]

With these views in mind, the primary objective of this study is to determine the effect water-based flexographic ink specifications have on the overall print quality of the finished product. The study will build on the work done in 1980 by George Huddleston of the Mainville Forest Products Corporation. Selected for study will be two inks that closely resemble the ink specifications identified by Mr. Huddleston in his study. The quantification of quality will be made by printing Universal Product Code (UPC) Symbols on single-wall corrugated board with the flexographic printing process, and observing the percentage of these symbols found to be printed within tolerance. These figures will then be compared to the percentage of symbols found to be printed within tolerance using a flexographic ink not in accordance with Huddleston's specifications.

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[12] Robert W. Elnfer, "Committed Management is Key to Quality Graphics on Corrugated," BOXBOARD CONTAINERS, October 1978, p. 49.

[13] Metzger, p. 3.

To date, there are no official corrugated industry flexographic ink standards, except those developed by specific companies for their own use. This study is not trying to develop industry-wide standards, nor is it suggesting that material standardization is a solution to a company's printing problems. The study is being conducted for the Jamestown Container Corporation and all findings and recommendations will be presented to them. If the test results within this study confirm that there is a distinct relationship between either the press, the inks, the printing plates, the press crew, or the substrate and print quality, more corrugated companies may begin to do further research into this area, and some form of industry-wide standardization may eventually be realized.

Limitations:

1. Flexographic printing on combined corrugated board is an all-encompassing process, involving variables such as moisture content of the board, warpage of the board, overall quality of the substrate, condition of the press, and condition of the printing plates. This study will focus only on the internal flexographic ink specifications identified by George Huddleston, the effect these specifications have on printed UPC symbols, and the percentage of these symbols found to be printed within tolerance. All other variables are held constant.

2. Chosen as the test instrument will be the UPC-A Symbol (found on grocery items). Using the UPC-A Symbol, which has a narrower tolerance range than the UPC Shipping Container Symbol, will result in some symbols being printed out of tolerance. This will be necessary in order to make a proper comparison of the two inks.

3. The UPC magnification density values of 1.20, 1.10, 1.00, 0.90, 0.80 will be used. Their specifications are listed in Table 1:

<u>Table 1</u>

UPC Symbol Specifications

Magnification Density	Narrow Bar Width	Print Tolerance	Allowable Tolerance Range
1.20	.0156"	+/- .0045"	.0111" - .0201"
1.10	.0143	+/- .0045	.0098 - .0188
1.00	.0130	+/- .0040	.0090 - .0170
0.90	.0117	+/- .0027	.0090 - .0144
0.80	.0104	+/- .0014	.0090 - .0118

4. Since a printed UPC Symbol may scan successfully yet still be out of tolerance, the symbols are measured to determine conformity to the established specifications presented in Table 1. Therefore, scanning is not necessary.

5. Due to the high cost of having inks specially made to match and/or fall below all the specifications

identified by George Huddleston, two inks will be chosen that most closely resemble his from a printability standpoint.

6. All tests will be performed using only one color, GCMI #31 blue of water-based flexographic ink.

Assumptions/Conditions:

1. There are currently no water-based flexographic ink standards existing at Jamestown Container.
2. All printing plates supplied for the UPC Symbol tests comply with the Universal Product Code Specifications Manual.
3. The UPC Symbols are printed with the bars oriented perpendicularly to the axis of the printing cylinder and parallel to the corrugated flutes.
4. There are no time limitations for setting up the press prior to the test run.
5. There are no speed limitations for the press during the printing of the UPC Symbols.
6. The ink used during the preliminary test does not meet all the flexographic ink specifications identified by George Huddleston.
7. Parameters are presented in Table 2, located on page 9.

Table 2

Parameters

The Corrugated Board:

Fifty sheets of 200# Single Wall B-Flute, Oyster White Board. A Blank Size = 30" x 30" to accommodate minimum sheet size through the printing press.

The Printing Press:

A Three-Color Flexo-Folder-Gluer by Bobst. The print cylinder size = 66". Anilox roll used during the study is a 200 line cell pyramid structure.

The Ink:

Preliminary Test Ink - General Printing Ink's HydroCorr 31-Blue. The Final Test Ink - General Printing Ink's Hydrotense 31-Blue. Ink color used will be 31 Blue.

The Printing Plates:

Photopolymer plates supplied premounted onto a non-compressible carrier sheet by Matrix Unlimited.

Specifications - Caliper = .250"
Relief Height = .100"
Carrier Sheet = .030"
Overall Caliper = .280"

CHAPTER 1

Early Studies

The amount of published literature focusing on the development of ink standards for the corrugated industry was found to be limited. Three articles were found describing tests either performed by specific companies for their own individual use, or conducted by companies in association with the Technical Association of the Pulp and Paper Industry (TAPPI) Container Division Printing Committee.

One such test was performed in 1975 by Dr. T. Kadai when he developed a quality control program for water-based flexographic corrugated inks for Consolidated-Bathurst Packaging Ltd. The first step in setting up the program was to determine what particular qualities in a flexographic ink were important to the corrugated converter.[14] The following water-based flexographic ink properties were determined to be important:

Specific Gravity	Foaming	Color Strength	Gloss[15]
pH	Drying Time	Particle Size	
Viscosity	Color	Rub Resistance	

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[14] Dr. T. Kadai, "A Quality Control Program For Flexo Corrugated Inks," BOXBOARD CONTAINERS, Summer 1975, p. 10.

[15] Ibid, p. 10.

Once these properties had been determined, standards were set and the program was implemented. The program helped to reduce press downtime and customer rejections due to print quality.[16] However, no mention was given to the particular standards or specific testing procedures used to determine whether or not corrugated flexographic ink standardization had in fact improved overall print quality. Kadai states, "The biggest benefit of the program results from the continuous policing of suppliers to ensure that we obtain top quality inks at the best possible price."[17]

Another study was performed in 1977 by Paul F. Pratte of the St. Regis Paper Company, in conjunction with the TAPPI Printing Committee. The purpose of the test was to measure the effects of some common elements found in the flexographic printing process.[18] The following variables were selected for the study: ink, anilox rolls, rubber wipe rolls, and printing plates. The main objective of the test was "... to measure the sharpness of printing, the uniformity of ink coverage, the reproduction accuracy of the artwork, and the clarity of printed halftones, linetones, etc."[19]

After setting the parameters and conducting the various test trials, much of the emphasis of the study shifted

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[16] Kadai, p. 13.

[17] Ibid, p. 13.

[18] Paul F. Pratte, "Quality Graphic Printing On Corrugated Board," 1978 TAPPI PROCEEDINGS, p. 25.

[19] Ibid, p. 26.

toward the reproduction accuracy of the halftones as a measure of press set-up and material selection.[20] In order to quantitatively measure the printing capabilities that were attainable in this test, Pratte measured the halftone density of the printed dots. He presented his test findings at the 1978 TAPPI Corrugated Containers Conference.

Pratte concluded that it is possible to print high quality graphics, that is, linetone, halftone, and so forth, on corrugated board with the flexographic printing process by controlling the ink film thickness. Pratte determined that the right combination of anilox roll and rubber wipe roll yielded the lowest level of ink film thickness and resulted in the best reproduction of the artwork used in the test. The most influential variable in quality was judged to be the printing plate itself. The photopolymer plate provided the finest reproduction of the halftone work and was deemed to be the best.

Pratte was careful to point out "... this study involved only one press and one set of conditions. If the study were to be extended to other presses, the same quality trends may be observed, but the final selection of equipment may be different."[21] In other words, due to the inherent differences among printing presses and the equipment used on these presses, another company could possibly find the final equipment selection, determined by this study to be the most

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[20] Pratte, p. 29.

[21] Ibid, p. 35.

appropriate, to be totally unacceptable for their needs and standards of quality.

The final test discussed here was performed in 1980 by George Huddleston of the Mainville Forest Products Corporation. Its objective was to find a way to improve the quality of graphics printed on clay-coated corrugated board.[22] Huddleston determined that the following are important characteristics which must first be considered when printing on corrugated board:

> 1) Since the liner is laid on a fluted material and glued, there are always soft spots or small valleys in the surface with which to contend.
>
> 2) The board varies up to +/- .020 inch in some spots, thus requiring constant adjustments in impression, and making necessary overcompensation in some areas.
>
> 3) The ink color varies on a printed surface.
>
> 4) Corrugated board absorbs ink like a sponge. However, it is not resilient. Hence, too much ink or too high an impression setting can ruin a board's physical properties.[23]

When the research project was started, Huddleston decided to first use the inks already in stock. A test plate was made and the tests were run on three types of corrugated stock: kraft, oyster white, and clay-coated board. The shelf-inks did not print well on any of the

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[22] George Huddleston, "New techniques to improve graphics on corrugated board," BOXBOARD CONTAINERS, December 1980, p. 45.

[23] Ibid, p. 45.

substrates, and particularly not on the clay-coated board. It was concluded that a new ink would have to be developed in order to print on the coated board.[24] Huddleston found 14 properties important in the development of a flexographic ink for clay-coated corrugated board. The performance specifications are as follows:

1) Viscosity - must be received at 22" #2 Zahn.
2) Color Strength - must maintain color at 18" #2 Zahn.
3) Odor - must have none after drying.
4) Fineness of Grind - must not exceed 3 over 3 using National Printing Ink Research Institute Grind Gauge.
5) Drying - must be within press speed capability, 50-700 fpm with no heat.
6) Rub - must perform well under 100-stroke weight Sutherland rub.
7) Fade - must perform well at 24-hour fade test.
8) Blocking - must not block at 5 psi-66% R.H.-140 degree F. for 24 hours.
9) Adhesion - No. 6 Scotch tape applied to dry print must pull paper fibre when removed.
10) Crease - must withstand 5 - 180 degree bends.
11) Abrasion - must perform well under 200 strokes, GRI Abrasion tester.
12) Color Correctness - must match standard.
13) pH - must be within a range of 8.2 to 8.5 pH.

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[24] Huddleston, p. 45.

14) Foaming - must show no foaming when shaken 5 minutes in Red Devil print shaker.[25]

After conducting further ink trials, Huddleston made the following conclusions:

1) An ink was being developed for clay-coated board.

2) The developed inks trapped and dried well.

3) The inks worked well on all three substrates.

4) A new plate system was needed.[26]

The plate trials were conducted to determine the effect of using various commercially available compressible backings in conjunction with photopolymer and natural rubber printing plates.[27] Huddleston conducted tests with various combinations of printing plates, some with and some without compressible backing materials, and recorded their impression ranges. He concluded that the use of a compressible backing material demonstrated the following advantages: better print results, wider operating latitudes, and reduced board crush.[28]

Of all the previously mentioned studies, the one conducted by Huddleston most closely resembles the one presented in this study. As was stated at the start of this chapter, research on flexographic ink standardization in the corrugated industry has been done by some individual

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[25] Huddleston, p. 48.

[26] Ibid, p. 49.

[27] Ibid, p. 49.

[28] Huddleston, p. 49.

companies. However, no evidence has been found of a company or organization that has used the Universal Product Code Symbol as a means of quantitatively measuring the overall effectiveness of such a program.

Chapter 2

Methodology

The study at hand will be using the performance specifications George Huddleston describes in his research[29] to determine the effect these water-based flexographic ink specifications have on the overall quality of the finished product. The quantification of quality will be made by printing Universal Product Code (UPC) Symbols on single-wall corrugated board with the flexographic printing process and observing the percentage of these symbols found to be printed within tolerance using Huddleston's ink specifications. These figures will then be compared to the percentage of symbols found to be printed within tolerance using a flexographic ink not in accordance with Huddleston's specifications.

This study and the one conducted by George Huddleston are comparable in that they both try to develop a relationship between ink specifications and the overall quality of the finished product. They differ, however, in the substrate, and possibly the testing instrument, used to draw the final conclusions. Huddleston's study was conducted to find a way to improve the quality of graphics

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[29] Huddleston, p. 48.

on clay-coated corrugated board[30]. Clay-coated board, as the name implies, is coated, thereby creating a non-absorbent sealed surface.[31] The coated surface represents a challenge to corrugated printing because the ink will no longer dry by absorbing into the paper fibers[32], and typically, corrugated printing presses are not equipped with between station dryers[33]. Since Huddleston could not rely on absorption or heat to dry the ink, it became necessary to develop a special flexographic ink with the physical properties enabling it to print and dry on clay-coated board[34]. Huddleston's study chose to concentrate on the aforementioned development. Although having the same main objective in mind, that being to improve the quality of graphics, the study at hand will not be using clay-coated corrugated board, but rather, oyster white corrugated board. This being the case, the ink will absorb into the paper fibers and, therefore, drying should present no problem.

Throughout Huddleston's study, no mention is given as to his testing instrument or the basis on which he made his observations and conclusions. For the purpose of this study, the UPC symbol will be used to provide the necessary quantitative information on which to base a decision. The

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[30] Huddleston, p. 45.

[31] Ibid, p. 45.

[32] Ibid, p. 48.

[33] The Flexographic Technical Association, Flexography: Principles and Practices, 1980, p. 206.

[34] Huddleston, p. 48.

UPC Symbol was chosen as the test instrument because of a study conducted in 1980 by Warren Taylor of the Rogers Corporation. Mr. Taylor used the UPC Symbol, printed on combined corrugated board, to compare conventional printing plates and thin printing plates, the latter being mounted on R-BAK material[35]. Mr. Taylor chose the UPC Symbol as a test instrument because "... it consists of long, slender bars, which represent a challenge to corrugated flexo printing."[36] Taylor adds, "... the image resolution of the UPC Symbol can be quantitatively measured, thereby providing information on how closely the printed symbol matched the film master."[37] These reasons give rise to incorporating the UPC Symbol as a test instrument into this study.

<u>Part I: Preliminary Test</u>

In order to determine the first ink's present capabilities, a preliminary test, conducted as follows, will be run using a flexographic ink not in accordance with the specifications identified by Huddleston. A UPC Symbol film master will be used to produce one set of photopolymer printing plates. The plates will be manufactured to basic corrugated industry standards and supplied, premounted onto the carrier sheet, by Matrix Unlimited.[38] Their

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[35] Warren F. Taylor, "Compressible backer improves printing on corrugated board," <u>BOXBOARD CONTAINERS</u>, July 1980, p. 34.

[36] Ibid, p. 34.

[37] Ibid, p. 35.

[38] Christopher Ritz, MATRIX UNLIMITED, Rochester, New York 14603.

specifications are listed in Table 2, page 9. The size limitations of Matrix Unlimited's photopolymer plate-making equipment allowed the printing plate to have only four UPC Symbols for each magnification value. The values are as follows: 1.20, 1.10, 1.00, 0.90, and 0.80, for a total of twenty symbols (4 symbols for each value) on the printing plate.

The printing plate will be mounted onto the print cylinder of the 200 cell anilox printing station. As listed in Table 2, page 9 (Parameters), in order to keep press time to a minimum, only 200 symbols per magnification will be printed. This will equal 50 corrugated sheets.

The printing ink used in the preliminary test will be a standard order kit of General Printing Ink's HydroCorr #31 Blue. The ink's specifications are not available from the manufacturer due to the proprietary nature of the subject. A letter was requested from the manufacturer verifying that the ink does not meet all the standards described by Huddleston. To date, no letter has been received.

<u>Part II: Technique Used For Collecting Data</u>

The procedure used for collecting data will be based on a technique adopted from Matrix Unlimited. The main objective will be to determine whether or not a UPC Symbol has been printed within its allowable tolerance. The technique will require the measuring of the first two narrow bars, found to the right of the zero, on each of the printed symbols. The measurements will be made with a 60x measuring microscope featuring a .1 inch field of view in .001 inch increments. Once the individual measurements have been made, the average of the two measurements will be taken and that average entered into the statistical software program SQCpack. The software will then determine the percentage of symbols printed out of tolerance by comparing the symbols' average to the tolerance specified for that magnification level. These findings will then be compared to the percentages found when the same procedure is performed with an ink similar to the one identified by Huddleston.

Accredited documentation verifying the above measuring procedure has not been found. On October 5, 1988, in hopes of locating a potential source, a telephone conversation with the Uniform Code Council verbally verified this procedure as being an appropriate way to determine whether or not UPC Symbols have been printed within their allowable tolerances. In a follow up to this conversation, a letter, a copy of which is located in Appendix B, was sent to Ms. Sharon Focht, President of the Uniform Code Council requesting a specific source or a letter from the Uniform Code Council formally verifying the procedure. To date, no letter has been received.

PART III. Final Test

Once the preliminary findings have been determined, the test will be repeated using a kit of General Printing Inks Hydrotense #31-Blue. A letter from the manufacturer stating how closely this ink matches the specifications identified by George Huddleston can be found in Appendix A. The symbols will be measured as specified in Part II, and the data entered into SQCpack. The averages will once again be compared to the specified tolerances. The results achieved during the preliminary test and the final test will be presented in the next chapter. All conclusions and recommendations will be made in the final chapter.

Chapter 3

Report on Study

The Preliminary Test:

As described in Chapter 2 (Methodology), fifty corrugated sheets, printed with General Printing Ink's HydroCorr #31 Blue, yielded a total of 1000 printed UPC Symbols (i.e., 200 symbols for each of the 5 magnification values). To determine the percentage of these symbols printed within their specified tolerances, the first two narrow bars on each of the printed symbols were measured with a 60x measuring microscope and the average was calculated.

One file was created for each of the 5 magnification values (1.20, 1.10, 1.00, 0.90 and 0.80). The symbols' averages, along with the upper and lower specification limits for each symbol's magnification value, were entered into the Variables Data Section of SQCpack. These values having been entered, the Histogram/Capability/Normal Probability Plot Menu was accessed. This function permits the creation of either a histogram or a normal probability plot of a variables data file.[39] The printout from the

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[39] Productivity - Quality Systems, Inc. SQCpack Version 3.10, p. 81.

histogram or normal probability plot contains statistical data calculated from the file being plotted.

SQCpack also evaluates, by using the chi-square test, the distribution for normality. Of the five plots generated during the preliminary test, only two (1.10 and 1.00) passed the chi-square test, and thus were considered to be a normal distribution by SQCpack. For this reason, rather than using the properties of the normal curve, the section of the histogram plot containing the actual percentages above and below specification was used to determine the percentage of symbols printed within tolerance. The histogram plots and their accompanying data for all five of the magnification values can be found in Appendix C.

Figure 2, page 25, is an example of a histogram plot from the preliminary test for the UPC Symbol magnification value of 0.90. For the purpose of clarifying the data contained in the charts hereafter, five main sections have been identified and are explained as follows:

> Section 1 - contains all the file summary information.
>
> Section 2 - contains the number of data points used as well as the sample Mean.
>
> Section 3 - contains the Upper and Lower Specification Limit, as well as the Nominal Value for the chosen symbol.
>
> Section 4 - contains the actual percentage of symbols printed Above, Below and Out of Specification.
>
> Section 5 - contains the actual Histogram/Capability Plot. Reading from left to right the symbols are as follows:

Preliminary Test Ink - 0.90 Mag.

1

File :90-CORR Date:05-05-1989, 13:55:28
Company :Jamestown Container Corporation
Plant :Jamestown Container Part name :HydroCorr
Department :Printing Part number :
Machine :Martin Sample frequency:All
Operation :Thesis Data Units :Inches
Characteristic :Preliminary Test Ink - 0.90 Mag.

Descriptive Statistics

All samples(n=4)

2 200 data points
Mean = 0.01254
Sigma Indiv= 0.00107
Est. Sigma = 0.00092
Coeff.Var. = 0.08523

Capability
Using Sigma Indiv

Cpk 0.58
Cp = 0.84
Cr = 1.19
Z upper 1.74
Z lower = 3.31

Min. Value = 0.0100
Max. Value 0.0160
Kurtosis = 0.314
Skewness = 0.464

4 Actual %
Above Spec = 6.50
Below Spec = 0.00
Out of Spec= 6.50

Theoretical %
Above Spec = 4.11
Below Spec = 0.05
Out of Spec= 4.16

Interval 0.00040
lower boundary
Chi Squared= 57.290
deg. free. 8
Conf. Level= 95%
Not Normal

3 Upper Spec.= 0.014[illegible]
Nominal 0.011[illegible]
Lower Spec. = 0.00900

5

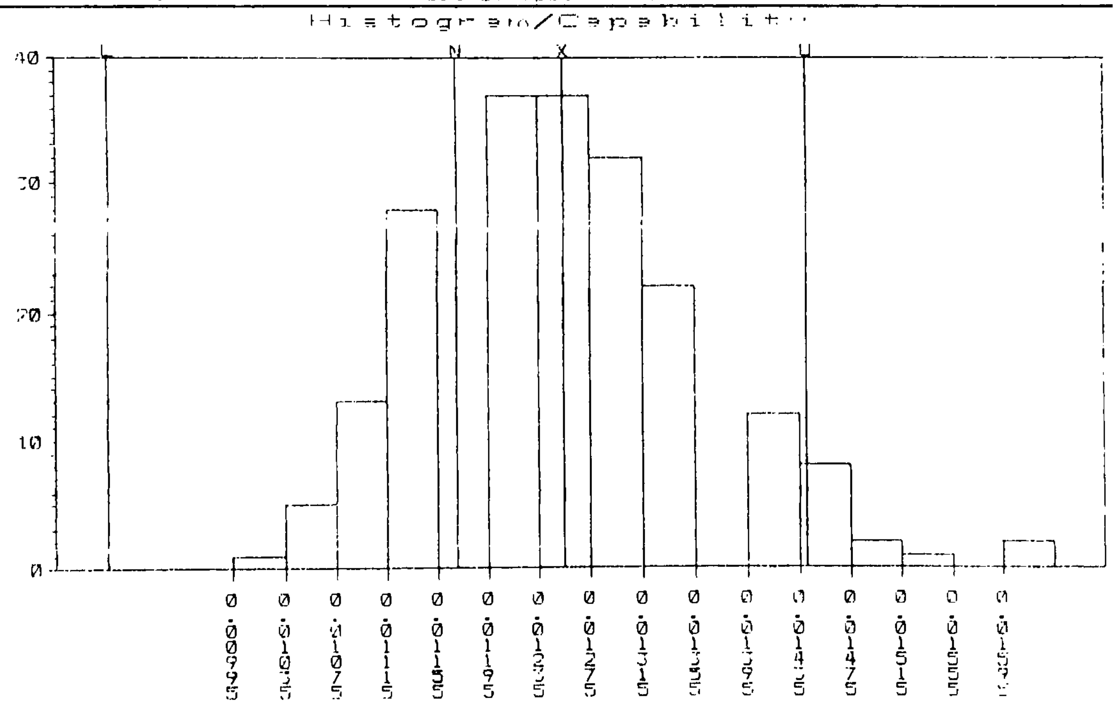

Figure 2

L = the Lower Specification Limit

N = the Nominal Value

X = the Sample Mean

U = the Upper Specification Limit.

It can be seen from Figure 2, page 25, that for the UPC Magnification Value of 0.90 (Section 1), 200 symbols (data points) were printed having a Mean of 0.01254 (Section 2). For this magnification value, a Nominal Value of 0.01170, with an Upper Specification Limit of 0.01440 and a Lower Specification Limit of 0.00900, is desirable (Section 3). Given these tolerances, 6.5% of the symbols have been printed Above Specification and 0.00 were printed Below Specification, yielding a total number of symbols printed Out of Specification as 6.5% (Section 4). Conversely, 93.5% of the 200 symbols printed were within the specified tolerance.

The Histogram/Capability Plot (Section 5) shows that the Sample Mean of the distribution (X) is located to the right of the Nominal Value (N) and below the Upper Specification Limit (U). The plot also shows that a certain percentage of the symbols have been printed above the Upper Specification Limit, while none are below the Lower Specification Limit (L). Table 3, page 27 contains the summary findings of the preliminary test.

Table 3

Summary Findings - Preliminary Test

Mag. Value	USL	Nominal	LSL	Percent Above	Percent Below	Percent In Spec
1.20	.0201	.0156	.0110	0.0%	0.0%	100.0%
1.10	.0188	.0143	.0098	0.0%	0.0%	100.0%
1.00	.0170	.0130	.0090	1.0%	0.0%	99.0%
0.90	.0144	.0117	.0090	6.5%	0.0%	93.5%
0.80	.0118	.0104	.0090	43.0%	0.0%	57.0%

The Final Test:

The final test was conducted exactly the same as the preliminary test. Once again, 50 corrugated sheets were printed, 200 for each of the five magnification values, yielding a total of 1000 printed UPC symbols. The determination of printing within tolerance was also made by measuring the first two narrow bars on each of the 200 UPC Symbols. Once these measurements were made, the averages were computed and entered into five separate files in SQCpack. However, the final test differs in that General Printing Ink's Hydrotense #31 Blue was used. The manufacturer ranks this ink slightly higher than the ink (HydroCorr) used during the preliminary test. Also, this ink more closely matches the specifications identified by Huddleston.

Of the five Histogram/Capability Plots generated, only one, that being for the Magnification Value of 1.00, was determined to be a normal distribution by SQCpack.

Therefore, the properties of the normal curve will once again not be used. The five plots and their accompanying data can be found in Appendix D. The interpretation of these plots is made in the same manner as that of the preliminary test. Table 4 contains the summary findings from the Final Test.

Table 4

Summary Findings - Final Test

Mag. Value	USL	Nominal	LSL	Percent Above	Percent Below	Percent In Spec
1.20	.0201	.0156	.0110	0.0%	0.0%	100.0%
1.10	.0188	.0143	.0098	0.0%	0.0%	100.0%
1.00	.0170	.0130	.0090	2.0%	0.0%	98.0%
0.90	.0144	.0117	.0090	10.0%	0.0%	90.0%
0.80	.0118	.0104	.0090	39.0%	0.0%	61.0%

A review of the summary findings from the Preliminary Test and the Final Test indicate that the test results are inconclusive. These findings will be discussed further in the last chapter, entitled Summary and Conclusions.

Chapter 4

Summary and Conclusions

In Chapter 3 (Report of Study) the findings from the preliminary test and the final test were presented, along with an example of how to interpret the Histogram/Capability Plots located in Appendices C and D. After reviewing the data in these Tables, the tests' results were determined to be inconclusive. This chapter will summarize the findings presented in the previous chapter and provide reasons as to why the results proved to be inconclusive.

Table 5 shows a composite summary for the percentage of symbols found to be printed within specification for each of the two tests conducted during this study.

<u>Table 5</u>

Data Summary of Study

Mag. Value	USL	Nominal	LSL	Preliminary Test % In Spec.	Final Test % In Spec.
1.20	.0201	.0156	.0110	100.0%	100.0%
1.10	.0188	.0143	.0098	100.0%	100.0%
1.00	.0170	.0130	.0090	99.0%	98.0%
0.90	.0144	.0117	.0090	93.5%	90.0%
0.80	.0118	.0104	.0090	57.0%	61.0%

It can be seen from Table 5, page 29, that for the UPC Symbol magnification values of 1.20 and 1.10, both inks resulted in all 200 of the UPC symbols being printed within tolerance; for the magnification values of 1.00 and 0.90 the Preliminary Test Ink performed slightly better than the Final Test Ink by 1.0% and 3.5%, respectively; and for the magnification value of 0.80, the Final Test Ink resulted in 4% more symbols being printed within tolerance. To summarize, even though the Final Test Ink was of slightly higher quality than the Preliminary Test Ink, it did not result in a higher percentage of symbols being printed within tolerance for all five magnification values, but rather, only one of the five.

Also revealed in the table is the fact that in both tests, as the magnification values decreases, and in turn narrows the width of the UPC Symbol's bars and the allowable tolerance ranges, the percentage of symbols printed within tolerance decreases. A review of the Histogram/Capability plots in Appendices C & D confirms this decrease. The plots show that as the magnification values decrease, the center or average of the Histogram Plots shift toward the right, that is, toward the Upper Specification Limits, and in one case, beyond this established limit. This shifting indicates that, on the average, the printed symbol's bars are exceeding the narrow-bar width requirements of the UPC Symbol specifications. Even though the Final Test Ink came closer than the Preliminary Test Ink to the specifications identified by Huddleston, it did not decrease the amount of shifting. In fact, a closer review indicates that as the magnification values decrease, the mean values of the Final Test Ink, as compared to those of the Preliminary Test Ink, shifted more toward the right. This shifting of both inks toward the Upper Specification Limits indicates that the choice of ink itself is not enough of an improvement to overcome the inability of the process to print such small magnification values. In other words, given all the factors that are involved in the printing of UPC Symbols on combined corrugated board with the flexographic printing process, simply changing the ink, without changing some or all of the other inputs, is not enough to allow such a small symbol and narrow tolerance range to be printed consistently within specification.

Another reason why the results have been deemed inconclusive is the close proximity in the percentage or the actual number of symbols printed within tolerance for the two tests. Table 6, page 32, is a comparison of the two tests, with the results presented as actual numbers rather than as percentages.

Table 6

Number of Symbols within Specification

Magnification Value	Preliminary Test Ink Number In Spec. Out of 200	Final Test Ink Number In Spec. Out of 200
1.20	200	200
1.10	200	200
1.00	198	196
0.90	187	180
0.80	114	122

It can be seen from Table 6 that the number of symbols printed within tolerance was comparable to that of the other test. In fact, the greatest difference between the two tests is a mere eight symbols. A review of the mean values in the Histogram Plots located in Appendices C and D also verifies the closeness of these results. The furthest apart any of the mean values are resulted in the magnification value of 1.00, with the difference in averages between the two tests being only .00136 inches. The data also shows that, on the average, the Preliminary Test Ink came closer than the Final Test Ink to meeting the nominal values required in the magnification ranges of 1.00 - 0.80. This closeness between the two tests implies that even though the Preliminary Test Ink did not meet Huddleston's parameters, it did perform as well as the Final Test Ink. Therefore, no appreciable difference in favor of the Final Test Ink could be determined.

The results of this study have been deemed inconclusive based on the following observations:

1. The Final Test Ink came closer to matching the specifications identified by Huddleston than the Preliminary Test Ink, but did not produce a higher percentage of symbols printed within tolerance for all 5 magnification values.
2. On the average, the Final Test Ink, as compared to the Preliminary Test Ink, produced a wider narrow bar width, thus shifting more toward the Upper Specification Limits.
3. There was a close proximity in the results of the two tests.

As stated earlier in this study, the primary objective of this research was to determine the effects water-based flexographic ink specifications have on the overall print quality of the finished product. The study would select two inks that closely resemble the flexographic ink specifications identified in 1980 by George Huddleston of the Mainville Forest Products Corporation. The quantification of quality would be made by printing Universal Product Code (UPC) Symbols on single-wall corrugated board with the flexographic printing process, using an ink resembling Huddleston's ink specifications, and by observing the percentage of these symbols found to be printed within tolerance. These results would then be compared to the percentage of symbols found to be printed within tolerance using a flexographic ink not in accordance to Huddleston's specifications.

The work presented in this study has addressed these points. However, because the results showed no appreciable difference between the two tests, the effect the water-based flexographic ink standards introduced by George Huddleston has on the overall print quality of the finished product, being in this case printed UPC Symbols, cannot be determined.

The work done in this study has, however, shown that the two selected inks yield similar results and are thus compatible from a printability standpoint. Currently, the Jamestown Container Corporation uses 18 different flexographic ink colors, one of which, GCMI 31-Blue, was incorporated into this study. Appendix E provides a cost savings summary based on the specific flexographic inks selected for this study.

It can be seen from Appendix E that if the Preliminary Test Ink is substituted for the Final Test Ink, an average annual savings of $38,190.75 would be incurred. Therefore, it will be recommended that Jamestown Container Corporation examine the possibility of substituting the Preliminary Test Ink for the Final Test Ink. If this recommendation is applied across the board, the cost savings could be tremendous. However, further research would be required to examine the performance of the Preliminary Test Ink from a marketing, or customer, stand point. Potential areas to examine would include the ink's rub resistance, gloss, fade, adhesion and ability to hold color.

It was stated in the Introduction that high quality graphics are the end result of the following five basic components: the press, the inks, the printing plates, the press crew, and the substrate.[40] All five of these factors must be optimum and based on continuing high standard in order to achieve a quality printing job. If any one of five components are less than perfect, quality printing can only be marginally achieved, and even then, not on a consistent basis.[41]

With this in mind, the study at hand focused on only one of the five basic components, that being the flexographic inks. The other four components were held constant. By using the work developed in this study and linking it with additional research in the area of one of the other four components, new insight into the variables of printing quality would be possible. Additional research may include, but is not limited to: reproducing this study with different combinations of linerboard and flute types; conducting this study on different makes and models of Flexo-Folder-Gluers; examining the effects of alternate printing plates; or performing this study with the same type of ink made by various manufacturers.

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[40] G. H. Anthony, "Rubber Printing Plate Capability," Paper, Film & Foil Converter, October 1983, p. 100.

[41] Ibid, p. 100.

APPENDICES

APPENDIX A

Sun Chemical Corporation **General Printing Ink Division**

7997 ALLISON AVE.
INDIANAPOLIS
INDIANA 46268
(317)-875-8666

April 18, 1988

Mr. Joseph Palmeri
Corporate Quality Director
PO Box 8
Jamestown, New York 14702-0008

Mr. Palmeri:

Further to our conversation today in reference to ink parameters on Hydrotense GCMI-31 Blue, please be advised of the following:

1.) Viscosity - shipped @ 30 sec. #2 Zahn.

2.) Color Strength - will maintain color @ 18 sec #2 Zahn (using a chrome 165 pyramid anilox roll) *If a finer line screen is employed, viscosity may need increasing to achieve correct color definition.

3.) Odor - none present after drying.

4.) Fineness of Grind - will not exceed 3 over 3 using a N.P.I.R.I. Grind Guage.

5.) Drying - will dry adequately within a given press speed (50-700 fpm) without heat assistance.

6.) Rub - will pass a 100 stroke, 2 lb. weight Sutherland Rub Test (dry).

7.) Fade - ink is not completely fade resistant for a 24 hour period.

8.) Blocking - no blocking test has been established.

9.) Adhesion - will pull paper fibres when no. 6 Scotch tape is applied to a dry print.

10.) Crease - no crease test has been established.

11.) Abrasion - test using the GRI Abrasion Tester have not been established.

12.) Color Correctness - ink will commercially match the ED VII GCMI Color Guide when proper substrate and recommended printing application guidelines are used.

13.) Ph - Range=8.2-8.5.

Sun Chemical Corporation General Printing Ink Division

7997 ALLISON AVE.
INDIANAPOLIS
INDIANA 46268
(317)-875-8666

14.) Foaming - minimal surface foam generated after being shaken on a Red Devil paint shaker.

The items discussed and listed will address your letter of March 10, 1988. I hope this information is sufficient for your needs however, if you have any questions, feel free to call.

Regards,

Kenney Parker /ta

Kenneth L. Parker
Laboratory Manager

KLP:ta

APPENDIX B

JAMESTOWN CONTAINER CORPORATION

Mailing Address:
P.O. Box 8
Jamestown, New York 14702-0008

716 / 665-4623

Factory:
150 South Phetteplace
Falconer, New York 14733

October 17, 1988

Ms. Sharon Focht
Uniform Code Council
P.O. Box 1244
Dayton, Ohio 45401

Dear Ms. Focht,

As a graduate student, completing work on my Master's Thesis at the Rochester Institute of Technology, I am required to determine whether or not UPC Symbols, printed on combined corrugated board with the flexographic printing process, have been done so within their allowable tolerances. The procedure, as I know it, is completed by measuring, with a measuring microscope, the first two narrow bars on each Symbol, and then, after taking the average, comparing this figure to the specified tolerance for that Symbol's magnification value.

In order to defend my choice of the aforementioned procedure as being the most appropriate way to determine if printing within tolerance has indeed occurred, I am required to have this measuring procedure formally documented by a recognized authority. To date, I have not been able to find this measuring procedure documented. For this reason, I am writing you, asking if you know of any formal documentation for this procedure. If so, could you refer me to the source, and if not, could you provide me with a letter verifying that this procedure is appropriate.

Enclosed please find a money order for $30.00 for one (1) copy of the UPC Symbol Specification Manual. I would also appreciate a copy of your Student Packet.

If you have any questions or need any additional information, please contact me.

Sincerely,

Joseph M. Palmeri

Joseph M. Palmeri
Corporate Quality Director

APPENDIX C

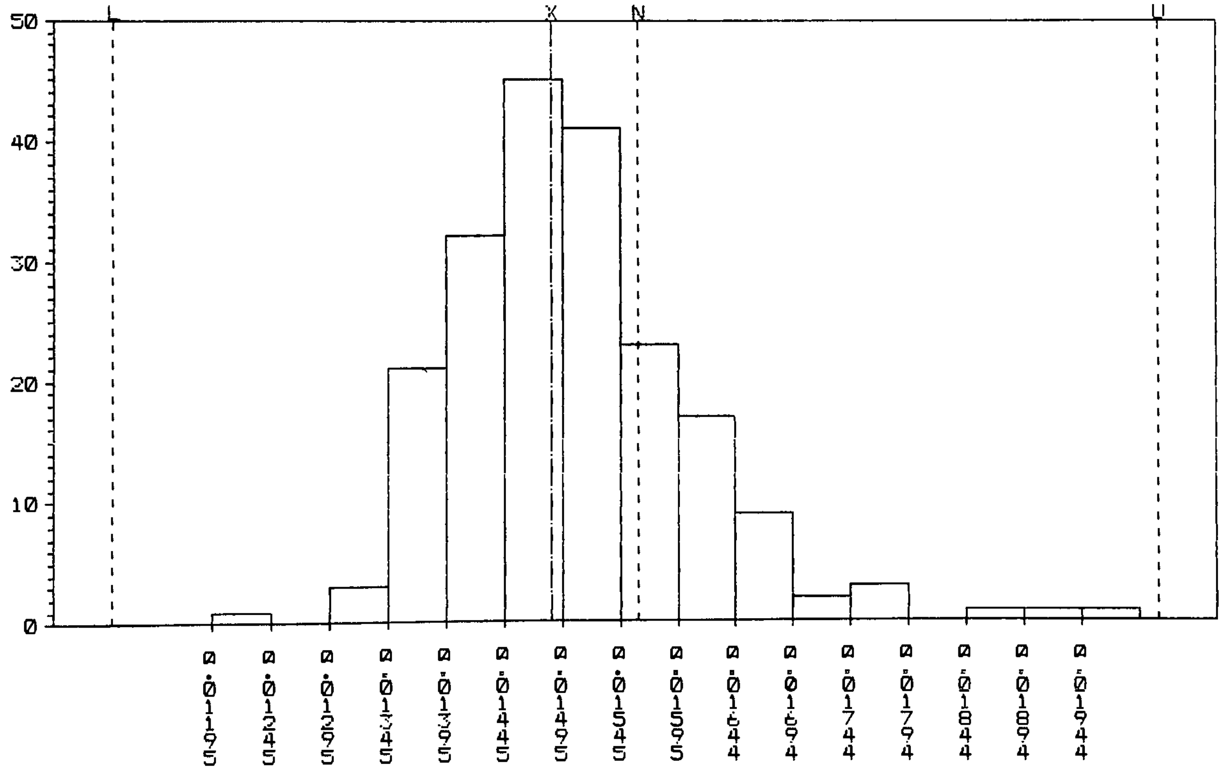
Preliminary Test Ink - 1.20 Mag.

File	:120-CORR	Date:09-07-1990, 10:44:09	
Company	:Jamestown Container Corporation		
Plant	:Jamestown Container	Part name	:HydroCorr
Department	:Printing	Part number	:*
Machine	:Martin	Sample frequency	:All
Operation	:Thesis Data	Units	:Inches
Characteristic	:Preliminary Test Ink - 1.20 Mag.		

Descriptive Statistics

All samples(n=4)		Interval = 0.00050
200 data points		lower boundary
Mean = 0.01485	Min. Value = 0.0120	Chi Squared= 16.023
Sigma Indiv= 0.00106	Max. Value = 0.0195	deg. free. = 6
Est. Sigma = 0.00082	Kurtosis = 2.529	Conf. Level= 95%
Coeff.Var. = 0.07166	Skewness = 1.045	Not Normal
Capability	Actual %	Upper Spec.= 0.02010
Using Sigma Indiv	Above Spec = 0.00	Nominal = 0.01560
	Below Spec = 0.00	Lower Spec.= 0.01110
Cpk = 1.18	Out of Spec= 0.00	
Cp = 1.41	Theoretical %	
Cr = 0.71	Above Spec = 0.00	
Z upper = 4.93	Below Spec = 0.02	
Z lower = 3.53	Out of Spec= 0.02	

Histogram/Capability



FILE: 120-CORR DATE: 09-07-1990

Plant....................Jamestown Container
Department................Printing
Machine...................Martin
Operation.................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01375	.0015	.01375	.00087		.0130	.0145	.0130	.0145
2	.01537	.0005	.01550	.00025		.0155	.0155	.0155	.0150
3	.01412	.0015	.01400	.00063		.0135	.0150	.0140	.0140
4	.01475	.0005	.01475	.00029		.0150	.0145	.0150	.0145
5	.01475	.0015	.01475	.00065		.0140	.0150	.0155	.0145
6	.01412	.0020	.01375	.00095		.0140	.0135	.0135	.0155
7	.01500	.0025	.01475	.00108		.0150	.0140	.0165	.0145
8	.01462	.0010	.01475	.00048		.0150	.0140	.0145	.0150
9	.01475	.0020	.01500	.00087		.0150	.0135	.0150	.0155
10	.01450	.0020	.01450	.00082		.0145	.0145	.0155	.0135
11	.01587	.0035	.01600	.00149		.0140	.0165	.0175	.0155
12	.01525	.0015	.01525	.00065		.0145	.0155	.0160	.0150
13	.01475	.0025	.01475	.00104		.0145	.0160	.0150	.0135
14	.01512	.0020	.01525	.00103		.0140	.0160	.0160	.0145
15	.01362	.0015	.01350	.00063		.0135	.0130	.0145	.0135
16	.01450	.0025	.01425	.00108		.0145	.0135	.0160	.0140
17	.01525	.0005	.01525	.00029		.0155	.0150	.0155	.0150
18	.01525	.0030	.01550	.00132		.0165	.0160	.0150	.0135
19	.01437	.0010	.01425	.00048		.0140	.0150	.0145	.0140
20	.01450	.0020	.01450	.00091		.0140	.0155	.0135	.0150
21	.01437	.0005	.01450	.00025		.0145	.0145	.0145	.0140
22	.01450	.0010	.01450	.00041		.0145	.0150	.0145	.0140
23	.01437	.0010	.01425	.00048		.0140	.0150	.0140	.0145
24	.01387	.0010	.01375	.00048		.0135	.0135	.0140	.0145
25	.01400	.0010	.01400	.00041		.0140	.0140	.0135	.0145
26	.01587	.0020	.01575	.00085		.0150	.0160	.0170	.0155
27	.01537	.0020	.01525	.00085		.0155	.0145	.0165	.0150
28	.01512	.0020	.01525	.00103		.0140	.0160	.0145	.0160
29	.01387	.0040	.01375	.00165		.0135	.0160	.0140	.0120
30	.01825	.0035	.01875	.00155		.0160	.0190	.0195	.0185
31	.01612	.0020	.01575	.00095		.0160	.0155	.0175	.0155
32	.01437	.0015	.01450	.00075		.0140	.0150	.0150	.0135
33	.01525	.0035	.01475	.00155		.0150	.0145	.0175	.0140
34	.01400	.0010	.01400	.00041		.0145	.0140	.0135	.0140
35	.01437	.0005	.01450	.00025		.0145	.0140	.0145	.0145
36	.01475	.0015	.01475	.00065		.0150	.0140	.0155	.0145
37	.01587	.0015	.01600	.00075		.0155	.0150	.0165	.0165
38	.01437	.0005	.01450	.00025		.0145	.0145	.0140	.0145
39	.01462	.0030	.01425	.00131		.0140	.0145	.0165	.0135
40	.01462	.0010	.01475	.00048		.0140	.0150	.0145	.0150
41	.01537	.0030	.01575	.00131		.0165	.0135	.0155	.0160
42	.01487	.0005	.01500	.00025		.0150	.0150	.0150	.0145
43	.01437	.0015	.01450	.00075		.0150	.0150	.0140	.0135
44	.01450	.0015	.01475	.00071		.0150	.0135	.0150	.0145
45	.01487	.0015	.01450	.00075		.0145	.0145	.0145	.0160
46	.01487	.0010	.01475	.00048		.0145	.0150	.0145	.0155
47	.01500	.0015	.01525	.00071		.0140	.0155	.0150	.0155
48	.01575	.0015	.01575	.00065		.0155	.0160	.0150	.0165
49	.01575	.0020	.01550	.00096		.0150	.0160	.0150	.0170
50	.01500	.0015	.01475	.00071		.0145	.0145	.0160	.0150

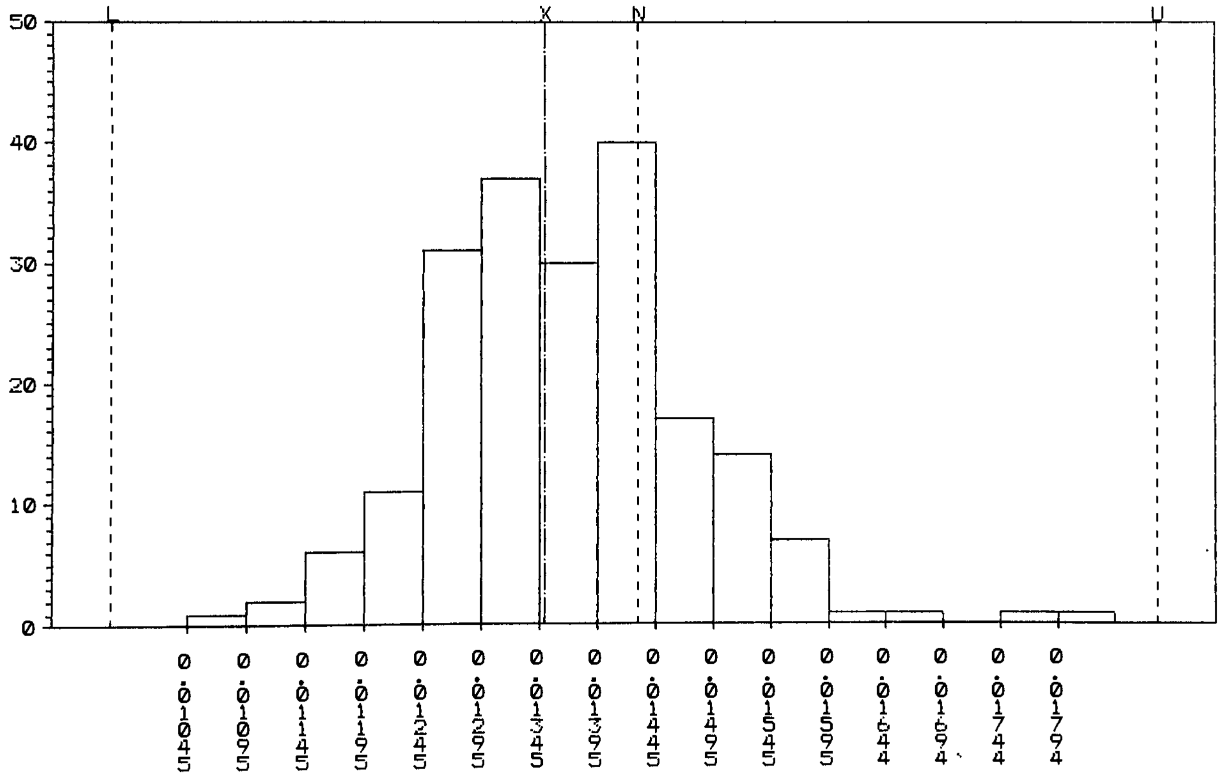
Preliminary Test Ink - 1.10 Mag.

File	:110-CORR	Date:09-07-1990, 10:45:31	
Company	:Jamestown Container Corporation		
Plant	:Jamestown Container	Part name	:HydroCorr
Department	:Printing	Part number	:*
Machine	:Martin	Sample frequency	:All
Operation	:Thesis Data	Units	:Inches
Characteristic	:Preliminary Test Ink - 1.10 Mag.		

Descriptive Statistics

All samples(n=4)		Interval = 0.00050
200 data points		lower boundary
Mean - 0.01350	Min. Value = 0.0105	Chi Squared= 13.869
Sigma Indiv= 0.00112	Max. Value = 0.0180	deg. free. = 7
Est. Sigma 0.00093	Kurtosis = 1.273	Conf. Level= 95%
Coeff.Var. - 0.08278	Skewness = 0.516	Normal
Capability	Actual %	Upper Spec.= 0.01880
Using Sigma Indiv	Above Spec = 0.00	Nominal = 0.01430
	Below Spec = 0.00	Lower Spec.= 0.00980
Cpk = 1.10	Out of Spec= 0.00	
Cp = 1.34	Theoretical %	
Cr = 0.74	Above Spec = 0.00	
Z upper = 4.74	Below Spec = 0.05	
Z lower = 3.31	Out of Spec= 0.05	

Histogram/Capability



FILE: 110-CORR DATE: 09-07-1990

Plant....................Jamestown Container
Department...............Printing
Machine..................Martin
Operation................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01325	.0030	.01300	.00126		.0130	.0130	.0120	.0150
2	.01400	.0020	.01400	.00115		.0130	.0150	.0130	.0150
3	.01350	.0025	.01325	.00122		.0125	.0150	.0125	.0140
4	.01350	.0020	.01350	.00091		.0125	.0130	.0140	.0145
5	.01375	.0020	.01400	.00087		.0125	.0140	.0140	.0145
6	.01287	.0010	.01275	.00048		.0130	.0135	.0125	.0125
7	.01262	.0005	.01250	.00025		.0125	.0125	.0130	.0125
8	.01337	.0010	.01325	.00048		.0140	.0130	.0135	.0130
9	.01375	.0020	.01400	.00087		.0125	.0140	.0140	.0145
10	.01200	.0020	.01150	.00100		.0115	.0115	.0115	.0135
11	.01375	.0015	.01375	.00065		.0130	.0145	.0135	.0140
12	.01375	.0025	.01375	.00104		.0125	.0140	.0135	.0150
13	.01312	.0020	.01325	.00103		.0120	.0125	.0140	.0140
14	.01387	.0015	.01400	.00063		.0140	.0130	.0145	.0140
15	.01325	.0015	.01325	.00065		.0140	.0135	.0130	.0125
16	.01325	.0020	.01350	.00096		.0140	.0130	.0140	.0120
17	.01337	.0010	.01325	.00048		.0130	.0140	.0130	.0135
18	.01312	.0015	.01300	.00063		.0140	.0130	.0125	.0130
19	.01400	.0020	.01400	.00091		.0150	.0145	.0130	.0135
20	.01375	.0015	.01375	.00065		.0140	.0135	.0145	.0130
21	.01362	.0005	.01350	.00025		.0135	.0135	.0140	.0135
22	.01225	.0010	.01250	.00050		.0125	.0115	.0125	.0125
23	.01312	.0010	.01325	.00048		.0130	.0125	.0135	.0135
24	.01237	.0030	.01275	.00131		.0130	.0135	.0105	.0125
25	.01287	.0035	.01300	.00149		.0135	.0125	.0110	.0145
26	.01450	.0035	.01425	.00147		.0130	.0145	.0140	.0165
27	.01437	.0015	.01450	.00075		.0135	.0150	.0140	.0150
28	.01375	.0020	.01400	.00096		.0135	.0145	.0125	.0145
29	.01362	.0020	.01375	.00085		.0125	.0135	.0145	.0140
30	.01662	.0025	.01650	.00131		.0155	.0155	.0175	.0180
31	.01487	.0025	.01500	.00111		.0135	.0155	.0145	.0160
32	.01400	.0025	.01375	.00122		.0155	.0145	.0130	.0130
33	.01362	.0010	.01375	.00048		.0135	.0140	.0140	.0130
34	.01287	.0005	.01300	.00025		.0130	.0130	.0130	.0125
35	.01250	.0015	.01225	.00071		.0120	.0125	.0135	.0120
36	.01337	.0025	.01350	.00111		.0140	.0120	.0130	.0145
37	.01312	.0020	.01325	.00103		.0125	.0120	.0140	.0140
38	.01387	.0020	.01375	.00085		.0130	.0140	.0150	.0135
39	.01250	.0020	.01250	.00091		.0120	.0115	.0135	.0130
40	.01350	.0010	.01350	.00041		.0130	.0135	.0135	.0140
41	.01450	.0025	.01475	.00122		.0130	.0140	.0155	.0155
42	.01375	.0015	.01375	.00065		.0130	.0140	.0145	.0135
43	.01262	.0015	.01250	.00063		.0125	.0120	.0125	.0135
44	.01362	.0010	.01375	.00048		.0135	.0130	.0140	.0140
45	.01362	.0025	.01350	.00111		.0125	.0140	.0150	.0130
46	.01312	.0030	.01325	.00138		.0125	.0140	.0115	.0145
47	.01262	.0030	.01275	.00125		.0130	.0140	.0125	.0110
48	.01350	.0030	.01350	.00173		.0120	.0150	.0120	.0150
49	.01425	.0030	.01450	.00132		.0125	.0150	.0140	.0155
50	.01412	.0015	.01400	.00063		.0140	.0135	.0140	.0150

Preliminary Test Ink - 1.00 Mag.

File :100-CORR Date:09-07-1990, 10:47:03
Company :Jamestown Container Corporation
Plant :Jamestown Container Part name :HydroCorr
Department :Printing Part number :*
Machine :Martin Sample frequency:All
Operation :Thesis Data Units :Inches
Characteristic :Preliminary Test Ink - 1.00 Mag.

Descriptive Statistics

All samples(n=4)
200 data points
Mean = 0.01339
Sigma Indiv= 0.00121
Est. Sigma = 0.00100
Coeff.Var. = 0.09059

Capability
Using Sigma Indiv

Cpk = 0.99
Cp = 1.10
Cr = 0.91
Z upper = 2.98
Z lower = 3.62

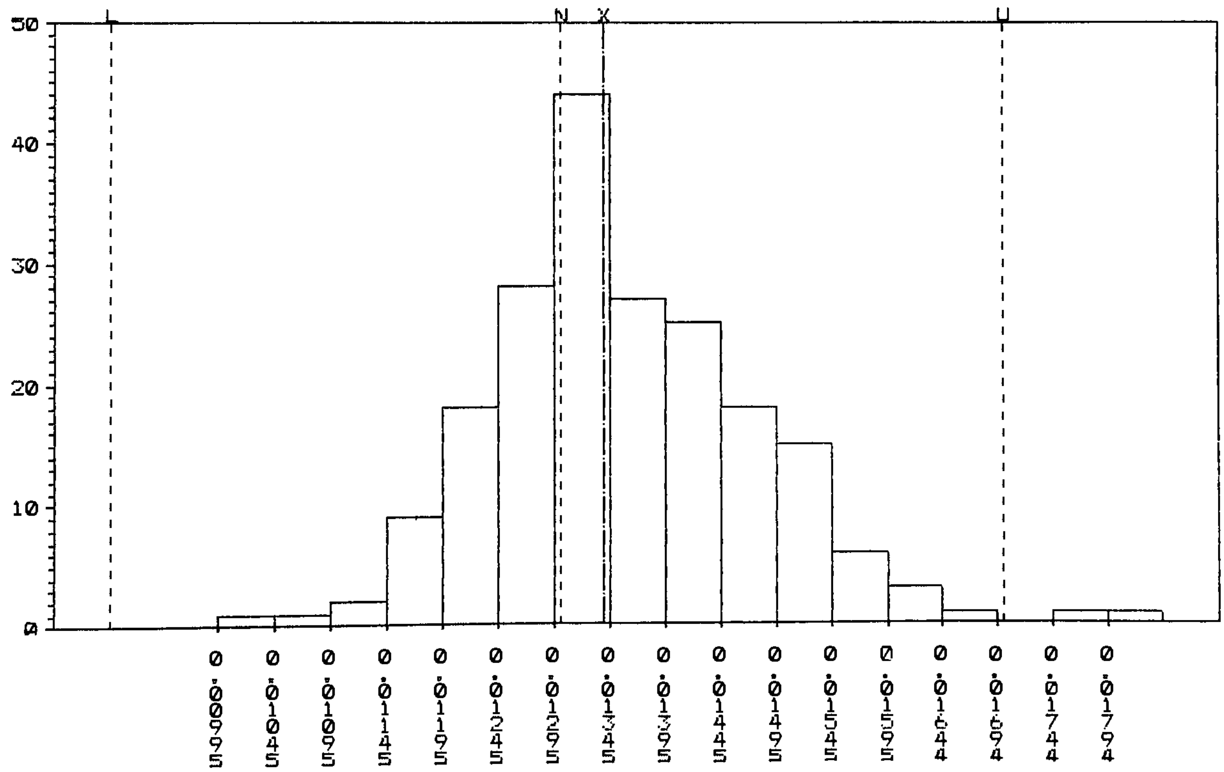
Min. Value = 0.0100
Max. Value = 0.0180
Kurtosis = 0.905
Skewness = 0.506

Actual %
Above Spec = 1.00
Below Spec = 0.00
Out of Spec= 1.00

Theoretical %
Above Spec = 0.14
Below Spec = 0.01
Out of Spec= 0.16

Interval = 0.00050
lower boundary
Chi Squared= 13.401
deg. free. = 7
Conf. Level= 95%
Normal
Upper Spec.= 0.01700
Nominal = 0.01300
Lower Spec.= 0.00900

Histogram/Capability



FILE: 100-CORR DATE: 09-07-1990

Plant....................Jamestown Container
Department...............Printing
Machine..................Martin
Operation................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01262	.0010	.01275	.00048		.0125	.0130	.0120	.0130
2	.01425	.0035	.01425	.00155		.0135	.0125	.0160	.0150
3	.01325	.0040	.01300	.00166		.0115	.0130	.0130	.0155
4	.01400	.0025	.01425	.00108		.0145	.0125	.0150	.0140
5	.01337	.0015	.01350	.00063		.0125	.0140	.0135	.0135
6	.01275	.0025	.01225	.00119		.0120	.0145	.0120	.0125
7	.01312	.0010	.01325	.00048		.0125	.0130	.0135	.0135
8	.01350	.0010	.01350	.00041		.0140	.0135	.0130	.0135
9	.01312	.0015	.01300	.00063		.0130	.0140	.0130	.0125
10	.01162	.0030	.01175	.00138		.0100	.0130	.0110	.0125
11	.01312	.0040	.01325	.00175		.0110	.0140	.0125	.0150
12	.01412	.0055	.01350	.00250		.0120	.0145	.0125	.0175
13	.01350	.0035	.01375	.00147		.0115	.0135	.0150	.0140
14	.01325	.0015	.01325	.00065		.0125	.0130	.0135	.0140
15	.01262	.0010	.01275	.00048		.0120	.0130	.0130	.0125
16	.01275	.0015	.01275	.00065		.0135	.0120	.0130	.0125
17	.01275	.0010	.01300	.00050		.0130	.0120	.0130	.0130
18	.01287	.0015	.01250	.00075		.0125	.0125	.0140	.0125
19	.01262	.0020	.01275	.00085		.0125	.0115	.0130	.0135
20	.01187	.0030	.01175	.00125		.0115	.0105	.0120	.0135
21	.01225	.0005	.01225	.00029		.0125	.0125	.0120	.0120
22	.01237	.0025	.01200	.00118		.0115	.0115	.0125	.0140
23	.01337	.0025	.01350	.00103		.0120	.0135	.0135	.0145
24	.01350	.0015	.01325	.00071		.0130	.0145	.0130	.0135
25	.01350	.0015	.01325	.00071		.0130	.0145	.0130	.0135
26	.01512	.0020	.01525	.00103		.0160	.0140	.0145	.0160
27	.01437	.0015	.01450	.00075		.0140	.0150	.0135	.0150
28	.01387	.0025	.01400	.00111		.0135	.0145	.0125	.0150
29	.01437	.0015	.01450	.00063		.0150	.0145	.0135	.0145
30	.01612	.0030	.01575	.00144		.0150	.0180	.0150	.0165
31	.01412	.0025	.01400	.00131		.0130	.0150	.0130	.0155
32	.01337	.0010	.01325	.00048		.0130	.0135	.0130	.0140
33	.01400	.0025	.01375	.00108		.0135	.0155	.0130	.0140
34	.01412	.0020	.01425	.00085		.0140	.0130	.0150	.0145
35	.01362	.0010	.01375	.00048		.0140	.0140	.0135	.0130
36	.01250	.0020	.01250	.00091		.0115	.0120	.0130	.0135
37	.01412	.0005	.01400	.00025		.0140	.0140	.0145	.0140
38	.01262	.0010	.01275	.00048		.0130	.0125	.0120	.0130
39	.01387	.0015	.01400	.00063		.0140	.0140	.0130	.0145
40	.01337	.0010	.01325	.00048		.0140	.0130	.0130	.0135
41	.01350	.0040	.01350	.00168		.0130	.0140	.0115	.0155
42	.01300	.0015	.01325	.00071		.0120	.0130	.0135	.0135
43	.01237	.0010	.01225	.00048		.0120	.0125	.0120	.0130
44	.01312	.0005	.01300	.00025		.0130	.0135	.0130	.0130
45	.01350	.0030	.01350	.00147		.0125	.0145	.0120	.0150
46	.01312	.0035	.01300	.00144		.0130	.0130	.0115	.0150
47	.01300	.0020	.01250	.00100		.0125	.0125	.0125	.0145
48	.01387	.0020	.01375	.00103		.0150	.0145	.0130	.0130
49	.01437	.0030	.01475	.00144		.0125	.0140	.0155	.0155
50	.01375	.0025	.01425	.00119		.0140	.0120	.0145	.0145

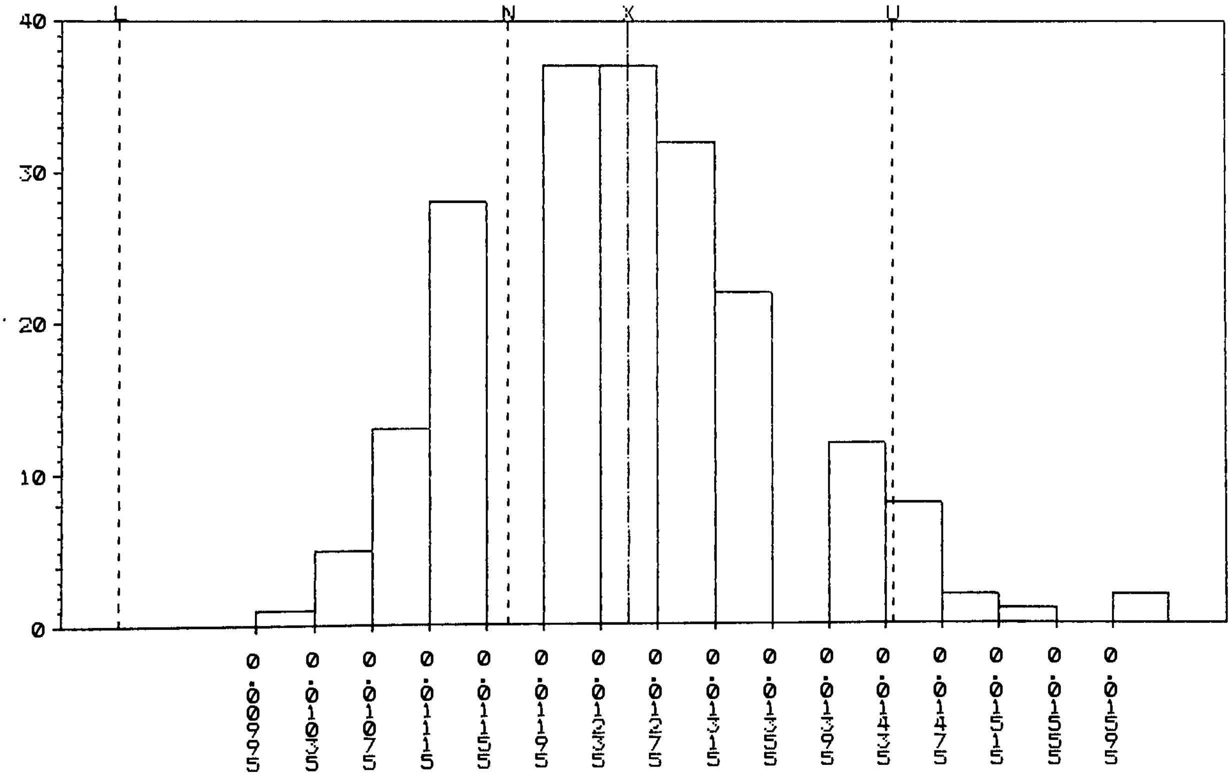
Preliminary Test Ink — 0.90 Mag.

File	:90-CORR	Date:09-07-1990, 10:48:20	
Company	:Jamestown Container Corporation		
Plant	:Jamestown Container	Part name	:HydroCorr
Department	:Printing	Part number	:*
Machine	:Martin	Sample frequency	:All
Operation	:Thesis Data	Units	:Inches
Characteristic	:Preliminary Test Ink - 0.90 Mag.		

Descriptive Statistics

All samples(n=4)			Interval = 0.00040
200 data points			lower boundary
Mean - 0.01254	Min. Value = 0.0100		Chi Squared= 57.290
Sigma Indiv= 0.00107	Max. Value = 0.0160		deg. free. = 8
Est. Sigma - 0.00092	Kurtosis = 0.314		Conf. Level= 95%
Coeff.Var. = 0.08523	Skewness = 0.464		Not Normal
Capability	Actual %		Upper Spec.= 0.01440
Using Sigma Indiv	Above Spec = 6.50		Nominal - 0.01170
	Below Spec = 0.00		Lower Spec.- 0.00900
Cpk = 0.58	Out of Spec= 6.50		
Cp = 0.84	Theoretical %		
Cr = 1.19	Above Spec = 4.11		
Z upper = 1.74	Below Spec = 0.05		
Z lower = 3.31	Out of Spec= 4.16		

Histogram/Capability



FILE: 90-CORR DATE: 09-07-1990

Plant....................Jamestown Container
Department...............Printing
Machine..................Martin
Operation................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01175	.0010	.01150	.00050		.0115	.0125	.0115	.0115
2	.01175	.0020	.01200	.00096		.0115	.0105	.0125	.0125
3	.01237	.0020	.01225	.00085		.0125	.0115	.0120	.0135
4	.01200	.0020	.01200	.00091		.0125	.0110	.0130	.0115
5	.01287	.0025	.01250	.00111		.0125	.0120	.0145	.0125
6	.01262	.0010	.01275	.00048		.0130	.0120	.0130	.0125
7	.01200	.0020	.01200	.00091		.0125	.0115	.0110	.0130
8	.01262	.0020	.01225	.00095		.0140	.0125	.0120	.0120
9	.01212	.0015	.01200	.00063		.0130	.0120	.0115	.0120
10	.01150	.0020	.01150	.00091		.0105	.0120	.0110	.0125
11	.01262	.0030	.01275	.00125		.0125	.0110	.0130	.0140
12	.01350	.0020	.01350	.00091		.0140	.0125	.0130	.0145
13	.01237	.0010	.01225	.00048		.0120	.0125	.0120	.0130
14	.01212	.0015	.01200	.00063		.0120	.0120	.0115	.0130
15	.01287	.0020	.01275	.00085		.0140	.0125	.0120	.0130
16	.01275	.0015	.01275	.00065		.0135	.0125	.0120	.0130
17	.01225	.0015	.01225	.00065		.0130	.0120	.0125	.0115
18	.01212	.0020	.01225	.00103		.0130	.0110	.0130	.0115
19	.01312	.0010	.01325	.00048		.0125	.0135	.0130	.0135
20	.01175	.0005	.01175	.00029		.0115	.0115	.0120	.0120
21	.01187	.0015	.01200	.00075		.0125	.0110	.0115	.0125
22	.01237	.0015	.01250	.00075		.0120	.0130	.0115	.0130
23	.01175	.0015	.01175	.00065		.0120	.0110	.0115	.0125
24	.01237	.0040	.01275	.00180		.0135	.0100	.0120	.0140
25	.01125	.0005	.01125	.00029		.0110	.0115	.0110	.0115
26	.01375	.0020	.01350	.00087		.0135	.0130	.0135	.0150
27	.01312	.0010	.01325	.00048		.0130	.0135	.0125	.0135
28	.01325	.0025	.01325	.00104		.0120	.0130	.0135	.0145
29	.01225	.0015	.01225	.00065		.0115	.0125	.0120	.0130
30	.01500	.0025	.01525	.00108		.0155	.0135	.0150	.0160
31	.01350	.0035	.01275	.00168		.0125	.0130	.0125	.0160
32	.01262	.0015	.01250	.00063		.0120	.0125	.0135	.0125
33	.01237	.0035	.01250	.00149		.0105	.0140	.0120	.0130
34	.01212	.0020	.01225	.00103		.0130	.0115	.0130	.0110
35	.01250	.0025	.01225	.00108		.0140	.0115	.0120	.0125
36	.01150	.0030	.01100	.00141		.0115	.0105	.0105	.0135
37	.01325	.0015	.01325	.00065		.0125	.0135	.0130	.0140
38	.01212	.0030	.01175	.00131		.0140	.0110	.0120	.0115
39	.01187	.0005	.01200	.00025		.0115	.0120	.0120	.0120
40	.01275	.0020	.01300	.00087		.0130	.0130	.0115	.0135
41	.01225	.0005	.01225	.00029		.0120	.0120	.0125	.0125
42	.01225	.0015	.01225	.00065		.0125	.0115	.0130	.0120
43	.01300	.0010	.01300	.00041		.0130	.0130	.0125	.0135
44	.01337	.0020	.01325	.00103		.0125	.0140	.0125	.0145
45	.01275	.0025	.01325	.00119		.0130	.0110	.0135	.0135
46	.01250	.0025	.01225	.00108		.0125	.0115	.0120	.0140
47	.01400	.0010	.01400	.00058		.0145	.0145	.0135	.0135
48	.01250	.0035	.01225	.00147		.0125	.0120	.0110	.0145
49	.01350	.0025	.01375	.00108		.0140	.0120	.0135	.0145
50	.01225	.0020	.01200	.00087		.0135	.0115	.0120	.0120

Preliminary Test Ink - 0.80 Mag.

File :80-CORR Date:09-07-1990, 10:49:35
Company :Jamestown Container Corporation
Plant :Jamestown Container
Department :Printing
Machine :Martin
Operation :Thesis Data
Characteristic :Preliminary Test Ink - 0.80 Mag.

Part name :HydroCorr
Part number :*
Sample frequency:All
Units :Inches

Descriptive Statistics

All samples(n=4)
200 data points
Mean = 0.01152
Sigma Indiv= 0.00092
Est. Sigma - 0.00080
Coeff.Var. - 0.07994

Capability
Using Sigma Indiv

Cpk - 0.10
Cp - 0.51
Cr - 1.97
Z upper = 0.31
Z lower 2.73

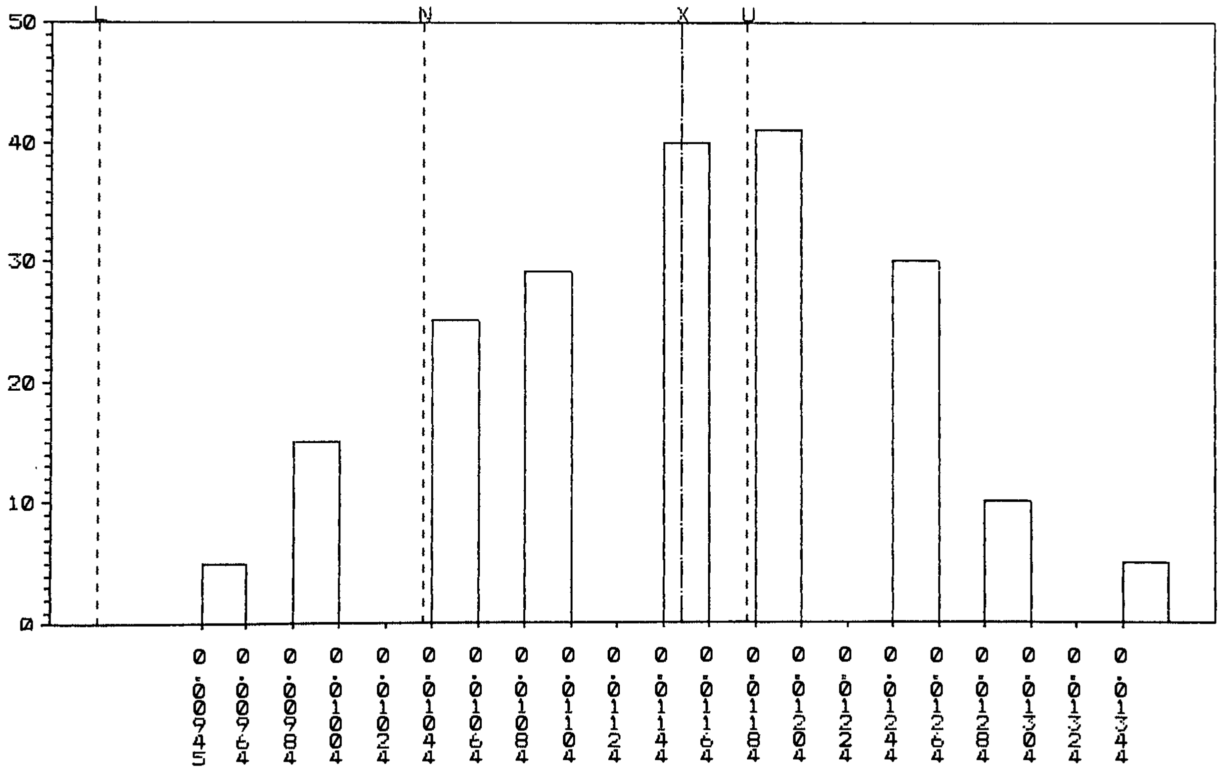
Min. Value = 0.0095
Max. Value = 0.0135
Kurtosis = -0.586
Skewness = -0.123

Actual %
Above Spec = 43.00
Below Spec = 0.00
Out of Spec= 43.00

Theoretical %
Above Spec = 37.95
Below Spec = 0.31
Out of Spec= 38.26

Interval 0.00020
lower boundary
Chi Squared=261.228
deg. free. - 14
Conf. Level= 95%
Not Normal
Upper Spec.= 0.01180
Nominal 0.01040
Lower Spec.- 0.00900

Histogram/Capability



FILE: 80-CORR DATE: 09-07-1990

Plant....................Jamestown Container
Department...............Printing
Machine..................Martin
Operation................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01125	.0015	.01125	.00087		.0105	.0120	.0120	.0105
2	.01087	.0020	.01125	.00095		.0115	.0095	.0110	.0115
3	.01137	.0025	.01100	.00118		.0105	.0105	.0115	.0130
4	.01125	.0020	.01150	.00087		.0100	.0115	.0115	.0120
5	.01062	.0015	.01050	.00063		.0100	.0105	.0115	.0105
6	.01162	.0015	.01150	.00075		.0110	.0120	.0125	.0110
7	.01150	.0030	.01100	.00141		.0105	.0135	.0115	.0105
8	.01137	.0010	.01125	.00048		.0110	.0110	.0115	.0120
9	.01100	.0015	.01075	.00071		.0110	.0105	.0105	.0120
10	.01150	.0035	.01125	.00147		.0135	.0100	.0115	.0110
11	.01200	.0020	.01200	.00091		.0130	.0115	.0110	.0125
12	.01162	.0020	.01175	.00085		.0125	.0115	.0105	.0120
13	.01150	.0015	.01125	.00071		.0125	.0115	.0110	.0110
14	.01200	.0015	.01225	.00071		.0110	.0125	.0125	.0120
15	.01187	.0015	.01200	.00063		.0120	.0125	.0120	.0110
16	.01087	.0015	.01100	.00075		.0115	.0105	.0115	.0100
17	.01112	.0020	.01125	.00085		.0120	.0110	.0115	.0100
18	.01087	.0010	.01075	.00048		.0110	.0105	.0115	.0105
19	.01087	.0020	.01125	.00095		.0095	.0115	.0110	.0115
20	.01125	.0015	.01125	.00065		.0105	.0120	.0115	.0110
21	.01050	.0010	.01050	.00041		.0100	.0110	.0105	.0105
22	.01112	.0015	.01100	.00063		.0120	.0110	.0110	.0105
23	.01012	.0020	.00975	.00095		.0100	.0095	.0115	.0095
24	.01125	.0005	.01125	.00029		.0110	.0115	.0110	.0115
25	.01100	.0015	.01075	.00071		.0120	.0110	.0105	.0105
26	.01212	.0010	.01225	.00048		.0125	.0120	.0115	.0125
27	.01137	.0020	.01175	.00095		.0120	.0100	.0115	.0120
28	.01150	.0020	.01150	.00091		.0105	.0110	.0120	.0125
29	.01087	.0015	.01100	.00075		.0115	.0105	.0100	.0115
30	.01325	.0005	.01325	.00029		.0135	.0135	.0130	.0130
31	.01212	.0005	.01200	.00025		.0120	.0120	.0125	.0120
32	.01100	.0015	.01125	.00071		.0115	.0100	.0115	.0110
33	.01162	.0020	.01175	.00085		.0115	.0105	.0120	.0125
34	.01087	.0030	.01075	.00138		.0115	.0095	.0125	.0100
35	.01162	.0010	.01175	.00048		.0115	.0110	.0120	.0120
36	.01100	.0020	.01100	.00091		.0105	.0115	.0120	.0100
37	.01275	.0015	.01275	.00065		.0125	.0130	.0135	.0120
38	.01187	.0025	.01250	.00125		.0125	.0100	.0125	.0125
39	.01212	.0005	.01200	.00025		.0120	.0120	.0125	.0120
40	.01212	.0010	.01225	.00048		.0120	.0115	.0125	.0125
41	.01187	.0010	.01175	.00048		.0125	.0115	.0115	.0120
42	.01150	.0030	.01150	.00129		.0110	.0100	.0130	.0120
43	.01162	.0015	.01150	.00075		.0110	.0120	.0125	.0110
44	.01212	.0020	.01225	.00085		.0130	.0120	.0125	.0110
45	.01187	.0010	.01175	.00048		.0115	.0125	.0120	.0115
46	.01162	.0020	.01175	.00085		.0120	.0115	.0125	.0105
47	.01212	.0010	.01225	.00048		.0125	.0120	.0125	.0115
48	.01200	.0030	.01250	.00141		.0130	.0130	.0120	.0100
49	.01237	.0010	.01225	.00048		.0120	.0125	.0130	.0120
50	.01212	.0010	.01225	.00048		.0120	.0125	.0125	.0115

APPENDIX D

Final Test Ink — 1.20 Mag.

File :120TENSE
Date:09-07-1990, 11:17:08
Company :Jamestown Container Corporation
Plant :Jamestown Container
Part name :HydroTense
Department :Printing
Part number :*
Machine :Martin
Sample frequency:All
Operation :Thesis Data
Units :Inches
Characteristic :Final Test Ink 1.20 Mag.

Descriptive Statistics

All samples(n=4)
200 data points
Mean = 0.01556
Sigma Indiv= 0.00110
Est. Sigma = 0.00080
Coeff.Var. = 0.07053

Capability
Using Sigma Indiv

Cpk = 1.35
Cp = 1.37
Cr = 0.73
Z upper = 4.14
Z lower = 4.06

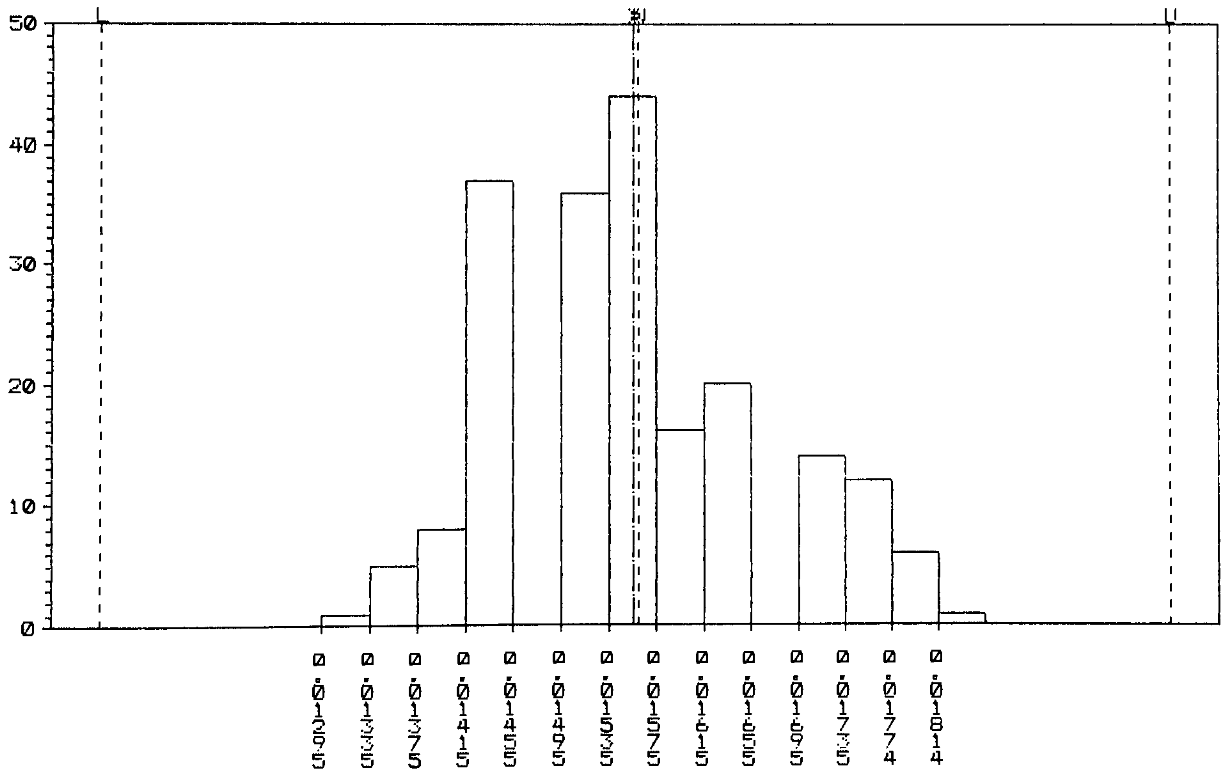
Min. Value = 0.0130
Max. Value = 0.0185
Kurtosis = -0.359
Skewness = 0.456

Actual %
Above Spec = 0.00
Below Spec = 0.00
Out of Spec= 0.00

Theoretical %
Above Spec 0.00
Below Spec = 0.00
Out of Spec= 0.00

Interval = 0.00040
lower boundary
Chi Squared= 92.848
deg. free. = 8
Conf. Level= 95%
Not Normal
Upper Spec.= 0.02010
Nominal = 0.01560
Lower Spec.= 0.01110

Histogram/Capability



FILE: 120TENSE DATE: 09-07-1990

Plant.....................Jamestown Container
Department................Printing
Machine...................Martin
Operation.................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01487	.0030	.01475	.00138		.0155	.0140	.0165	.0135
2	.01462	.0015	.01450	.00063		.0145	.0140	.0155	.0145
3	.01500	.0025	.01525	.00108		.0135	.0150	.0160	.0155
4	.01487	.0015	.01500	.00063		.0150	.0140	.0150	.0155
5	.01587	.0015	.01600	.00075		.0150	.0165	.0155	.0165
6	.01487	.0005	.01500	.00025		.0145	.0150	.0150	.0150
7	.01450	.0010	.01450	.00041		.0145	.0145	.0140	.0150
8	.01512	.0015	.01500	.00075		.0155	.0145	.0145	.0160
9	.01512	.0015	.01550	.00075		.0140	.0155	.0155	.0155
10	.01500	.0010	.01500	.00041		.0150	.0145	.0155	.0150
11	.01537	.0020	.01525	.00085		.0165	.0145	.0150	.0155
12	.01500	.0015	.01475	.00071		.0150	.0145	.0160	.0145
13	.01450	.0020	.01450	.00091		.0135	.0140	.0155	.0150
14	.01625	.0015	.01625	.00065		.0155	.0160	.0170	.0165
15	.01462	.0005	.01450	.00025		.0145	.0145	.0150	.0145
16	.01525	.0020	.01500	.00087		.0165	.0150	.0145	.0150
17	.01500	.0010	.01500	.00058		.0155	.0145	.0155	.0145
18	.01537	.0015	.01550	.00063		.0155	.0145	.0160	.0155
19	.01500	.0015	.01475	.00071		.0145	.0145	.0150	.0160
20	.01462	.0020	.01475	.00085		.0135	.0145	.0155	.0150
21	.01475	.0005	.01475	.00029		.0150	.0145	.0150	.0145
22	.01687	.0030	.01675	.00160		.0180	.0155	.0185	.0155
23	.01662	.0015	.01650	.00075		.0160	.0175	.0170	.0160
24	.01625	.0025	.01625	.00119		.0150	.0155	.0170	.0175
25	.01537	.0005	.01550	.00025		.0155	.0155	.0150	.0155
26	.01737	.0005	.01750	.00025		.0175	.0175	.0170	.0175
27	.01725	.0015	.01725	.00065		.0165	.0175	.0180	.0170
28	.01725	.0020	.01750	.00087		.0180	.0160	.0175	.0175
29	.01612	.0025	.01650	.00111		.0145	.0165	.0170	.0165
30	.01662	.0025	.01650	.00103		.0165	.0155	.0165	.0180
31	.01675	.0015	.01675	.00065		.0160	.0170	.0175	.0165
32	.01550	.0030	.01550	.00122		.0155	.0140	.0155	.0170
33	.01487	.0010	.01475	.00048		.0155	.0150	.0145	.0145
34	.01550	.0020	.01550	.00082		.0145	.0155	.0165	.0155
35	.01700	.0015	.01675	.00071		.0165	.0165	.0170	.0180
36	.01550	.0010	.01550	.00041		.0155	.0160	.0150	.0155
37	.01512	.0005	.01500	.00025		.0150	.0150	.0155	.0150
38	.01412	.0030	.01375	.00131		.0135	.0130	.0140	.0160
39	.01500	.0010	.01500	.00041		.0150	.0145	.0155	.0150
40	.01487	.0010	.01475	.00048		.0150	.0145	.0155	.0145
41	.01550	.0030	.01500	.00141		.0145	.0155	.0145	.0175
42	.01537	.0015	.01500	.00075		.0165	.0150	.0150	.0150
43	.01675	.0015	.01675	.00065		.0175	.0170	.0165	.0160
44	.01587	.0020	.01625	.00095		.0160	.0165	.0165	.0145
45	.01687	.0015	.01700	.00063		.0160	.0170	.0170	.0175
46	.01625	.0025	.01575	.00119		.0155	.0180	.0160	.0155
47	.01550	.0015	.01525	.00071		.0150	.0150	.0155	.0165
48	.01550	.0000	.01550	.00000		.0155	.0155	.0155	.0155
49	.01550	.0025	.01525	.00108		.0170	.0155	.0150	.0145
50	.01512	.0025	.01450	.00125		.0145	.0145	.0170	.0145

Final Test Ink — 1.10 Mag.

File :110TENSE Date:09-07-1990, 11:18:43
Company :Jamestown Container Corporation
Plant :Jamestown Container
Department :Printing
Machine :Martin
Operation :Thesis
Characteristic :Final Test Ink - 1.10 Mag.

Part name :HydroTense
Part number :*
Sample frequency:All
Units :Inches

Descriptive Statistics

All samples(n=4)
200 data points
Mean = 0.01429
Sigma Indiv= 0.00121
Est. Sigma = 0.00088
Coeff.Var. = 0.08475

Capability
Using Sigma Indiv

Cpk = 1.24
Cp = 1.24
Cr = 0.81
Z upper = 3.72
Z lower = 3.71

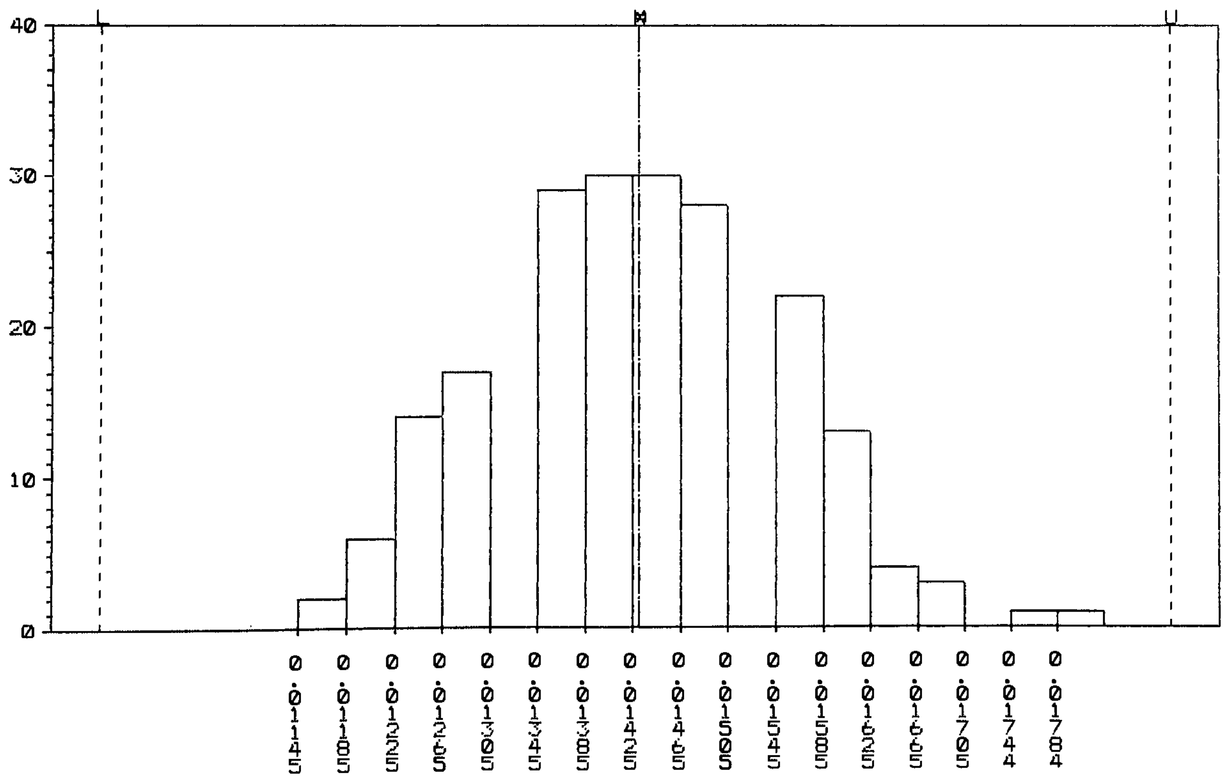
Min. Value 0.0115
Max. Value = 0.0180
Kurtosis - -0.202
Skewness = 0.139

Actual %
Above Spec - 0.00
Below Spec - 0.00
Out of Spec= 0.00

Theoretical %
Above Spec - 0.01
Below Spec - 0.01
Out of Spec= 0.02

Interval = 0.00040
lower boundary
Chi Squared= 52.854
deg. free. = 10
Conf. Level= 95%
Not Normal
Upper Spec.= 0.01880
Nominal = 0.01430
Lower Spec.= 0.00980

Histogram/Capability



FILE: 110TENSE DATE: 09-07-1990

Plant....................Jamestown Container
Department...............Printing
Machine..................Martin
Operation................Thesis

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01362	.0025	.01350	.00103		.0125	.0135	.0135	.0150
2	.01450	.0020	.01450	.00091		.0150	.0135	.0140	.0155
3	.01325	.0015	.01325	.00065		.0140	.0125	.0135	.0130
4	.01350	.0025	.01325	.00108		.0135	.0130	.0125	.0150
5	.01387	.0030	.01375	.00138		.0145	.0130	.0125	.0155
6	.01425	.0025	.01425	.00104		.0145	.0130	.0140	.0155
7	.01337	.0010	.01325	.00048		.0130	.0130	.0135	.0140
8	.01287	.0015	.01250	.00075		.0125	.0125	.0125	.0140
9	.01412	.0015	.01400	.00075		.0135	.0135	.0150	.0145
10	.01437	.0025	.01400	.00118		.0135	.0135	.0145	.0160
11	.01437	.0005	.01450	.00025		.0145	.0145	.0145	.0140
12	.01387	.0025	.01400	.00103		.0140	.0125	.0150	.0140
13	.01387	.0010	.01375	.00048		.0135	.0135	.0145	.0140
14	.01412	.0010	.01425	.00048		.0145	.0140	.0135	.0145
15	.01387	.0010	.01375	.00048		.0135	.0140	.0145	.0135
16	.01375	.0030	.01350	.00132		.0125	.0140	.0130	.0155
17	.01362	.0005	.01350	.00025		.0135	.0140	.0135	.0135
18	.01325	.0020	.01350	.00087		.0140	.0135	.0120	.0135
19	.01387	.0020	.01375	.00085		.0130	.0140	.0135	.0150
20	.01275	.0020	.01250	.00087		.0120	.0125	.0125	.0140
21	.01300	.0020	.01300	.00091		.0135	.0140	.0120	.0125
22	.01562	.0015	.01550	.00063		.0150	.0155	.0165	.0155
23	.01512	.0025	.01500	.00111		.0155	.0165	.0140	.0145
24	.01437	.0010	.01425	.00048		.0145	.0140	.0140	.0150
25	.01550	.0025	.01525	.00122		.0170	.0160	.0145	.0145
26	.01650	.0020	.01650	.00082		.0165	.0175	.0165	.0155
27	.01625	.0030	.01600	.00150		.0150	.0170	.0150	.0180
28	.01575	.0010	.01600	.00050		.0160	.0160	.0150	.0160
29	.01512	.0025	.01450	.00125		.0145	.0145	.0145	.0170
30	.01500	.0020	.01500	.00082		.0140	.0160	.0150	.0150
31	.01537	.0015	.01550	.00075		.0145	.0160	.0160	.0150
32	.01375	.0030	.01400	.00126		.0140	.0120	.0140	.0150
33	.01487	.0015	.01500	.00075		.0145	.0140	.0155	.0155
34	.01500	.0015	.01475	.00071		.0160	.0145	.0145	.0150
35	.01550	.0010	.01550	.00041		.0155	.0150	.0160	.0155
36	.01375	.0040	.01400	.00185		.0115	.0130	.0150	.0155
37	.01262	.0010	.01275	.00048		.0120	.0130	.0125	.0130
38	.01312	.0010	.01325	.00048		.0135	.0135	.0130	.0125
39	.01337	.0010	.01325	.00048		.0130	.0130	.0140	.0135
40	.01262	.0025	.01250	.00111		.0130	.0115	.0120	.0140
41	.01375	.0025	.01325	.00119		.0130	.0135	.0130	.0155
42	.01462	.0020	.01475	.00085		.0135	.0145	.0155	.0150
43	.01550	.0010	.01550	.00041		.0155	.0150	.0160	.0155
44	.01487	.0015	.01500	.00063		.0155	.0150	.0150	.0140
45	.01462	.0015	.01500	.00075		.0150	.0135	.0150	.0150
46	.01512	.0015	.01500	.00075		.0145	.0145	.0155	.0160
47	.01462	.0010	.01475	.00048		.0150	.0145	.0140	.0150
48	.01475	.0015	.01475	.00065		.0155	.0140	.0145	.0150
49	.01500	.0020	.01500	.00091		.0160	.0145	.0155	.0140
50	.01450	.0020	.01450	.00082		.0135	.0145	.0145	.0155

Final Test Ink — 1.00 Mag.

File :100TENSE Date:09-07-1990, 11:20:08
Company :Jamestown Container Corporation
Plant :Jamestown Container Part name :HydroTense
Department :Printing Part number :*
Machine :Martin Sample frequency:All
Operation :Thesis Data Units :Inches
Characteristic :Final Test Ink - 1.00 Mag.

Descriptive Statistics

All samples(n=4)
200 data points
Mean = 0.01475
Sigma Indiv= 0.00131
Est. Sigma = 0.00114
Coeff.Var. = 0.08878

Capability
Using Sigma Indiv

Cpk = 0.57
Cp = 1.02
Cr = 0.98
Z upper = 1.71
Z lower = 4.39

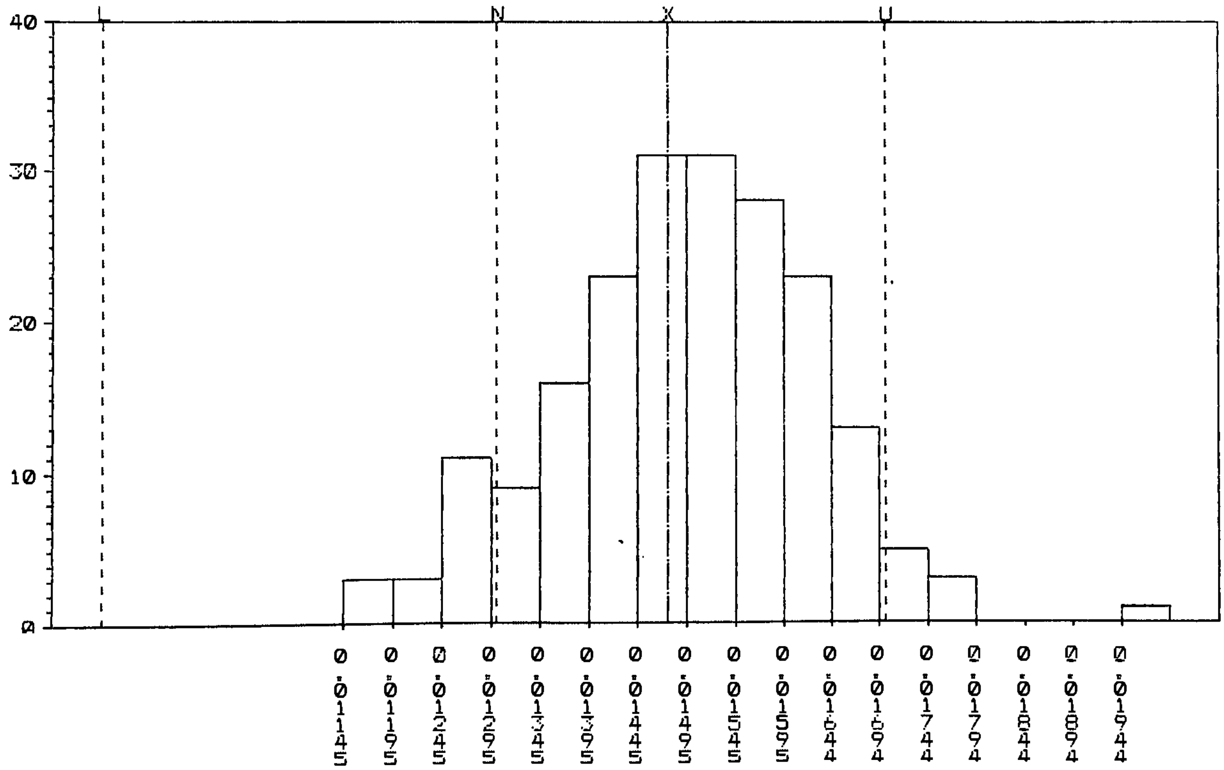
Min. Value = 0.0115
Max. Value = 0.0195
Kurtosis = 0.252
Skewness = -0.071

Actual %
Above Spec = 2.00
Below Spec = 0.00
Out of Spec= 2.00

Theoretical %
Above Spec = 4.33
Below Spec = 0.00
Out of Spec= 4.33

Interval = 0.00050
lower boundary
Chi Squared= 10.354
deg. free. = 8
Conf. Level= 95%
Normal
Upper Spec.= 0.01700
Nominal = 0.01300
Lower Spec.= 0.00900

Histogram/Capability



FILE: 100TENSE

DATE: 09-07-1990

Plant....................Jamestown Container
Department...............Printing
Machine..................Martin
Operation................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01462	.0030	.01425	.00131		.0135	.0145	.0140	.0165
2	.01450	.0025	.01425	.00122		.0135	.0150	.0135	.0160
3	.01462	.0030	.01425	.00131		.0140	.0145	.0165	.0135
4	.01337	.0020	.01325	.00085		.0125	.0130	.0145	.0135
5	.01362	.0030	.01425	.00144		.0115	.0140	.0145	.0145
6	.01425	.0035	.01425	.00155		.0135	.0125	.0150	.0160
7	.01487	.0020	.01475	.00085		.0150	.0140	.0145	.0160
8	.01425	.0015	.01425	.00065		.0150	.0140	.0135	.0145
9	.01375	.0045	.01375	.00194		.0115	.0145	.0130	.0160
10	.01425	.0015	.01425	.00065		.0135	.0140	.0150	.0145
11	.01362	.0030	.01375	.00138		.0130	.0145	.0120	.0150
12	.01450	.0035	.01475	.00158		.0125	.0160	.0140	.0155
13	.01425	.0025	.01475	.00119		.0150	.0125	.0150	.0145
14	.01300	.0025	.01325	.00108		.0115	.0135	.0130	.0140
15	.01362	.0030	.01325	.00131		.0125	.0135	.0130	.0155
16	.01412	.0010	.01425	.00048		.0135	.0145	.0140	.0145
17	.01450	.0040	.01500	.00173		.0120	.0150	.0160	.0150
18	.01400	.0030	.01400	.00122		.0125	.0155	.0140	.0140
19	.01500	.0015	.01475	.00071		.0150	.0145	.0145	.0160
20	.01325	.0015	.01325	.00065		.0140	.0135	.0125	.0130
21	.01450	.0015	.01425	.00071		.0140	.0145	.0140	.0155
22	.01575	.0030	.01550	.00132		.0160	.0175	.0145	.0150
23	.01600	.0010	.01600	.00058		.0165	.0155	.0155	.0165
24	.01537	.0015	.01550	.00075		.0145	.0160	.0150	.0160
25	.01587	.0010	.01575	.00048		.0160	.0165	.0155	.0155
26	.01512	.0015	.01500	.00063		.0150	.0160	.0145	.0150
27	.01537	.0030	.01525	.00160		.0140	.0165	.0140	.0170
28	.01550	.0015	.01575	.00071		.0160	.0160	.0155	.0145
29	.01487	.0010	.01475	.00048		.0150	.0145	.0155	.0145
30	.01475	.0030	.01500	.00132		.0145	.0160	.0130	.0155
31	.01562	.0020	.01575	.00085		.0145	.0155	.0165	.0160
32	.01525	.0015	.01525	.00065		.0155	.0145	.0150	.0160
33	.01625	.0005	.01625	.00029		.0160	.0165	.0165	.0160
34	.01562	.0015	.01550	.00063		.0165	.0155	.0150	.0155
35	.01700	.0040	.01650	.00178		.0160	.0170	.0155	.0195
36	.01550	.0030	.01550	.00173		.0140	.0170	.0140	.0170
37	.01437	.0025	.01450	.00131		.0130	.0155	.0135	.0155
38	.01425	.0015	.01425	.00065		.0135	.0145	.0150	.0140
39	.01375	.0030	.01400	.00132		.0120	.0135	.0150	.0145
40	.01425	.0050	.01350	.00236		.0125	.0145	.0125	.0175
41	.01425	.0040	.01400	.00166		.0125	.0140	.0140	.0165
42	.01450	.0040	.01450	.00168		.0125	.0150	.0140	.0165
43	.01525	.0015	.01525	.00065		.0155	.0160	.0145	.0150
44	.01550	.0010	.01550	.00058		.0160	.0150	.0150	.0160
45	.01512	.0010	.01525	.00048		.0145	.0155	.0155	.0150
46	.01562	.0020	.01525	.00095		.0150	.0150	.0170	.0155
47	.01550	.0015	.01525	.00071		.0150	.0150	.0155	.0165
48	.01487	.0020	.01525	.00095		.0155	.0135	.0150	.0155
49	.01525	.0010	.01550	.00050		.0155	.0155	.0155	.0145
50	.01487	.0045	.01450	.00193		.0150	.0130	.0140	.0175

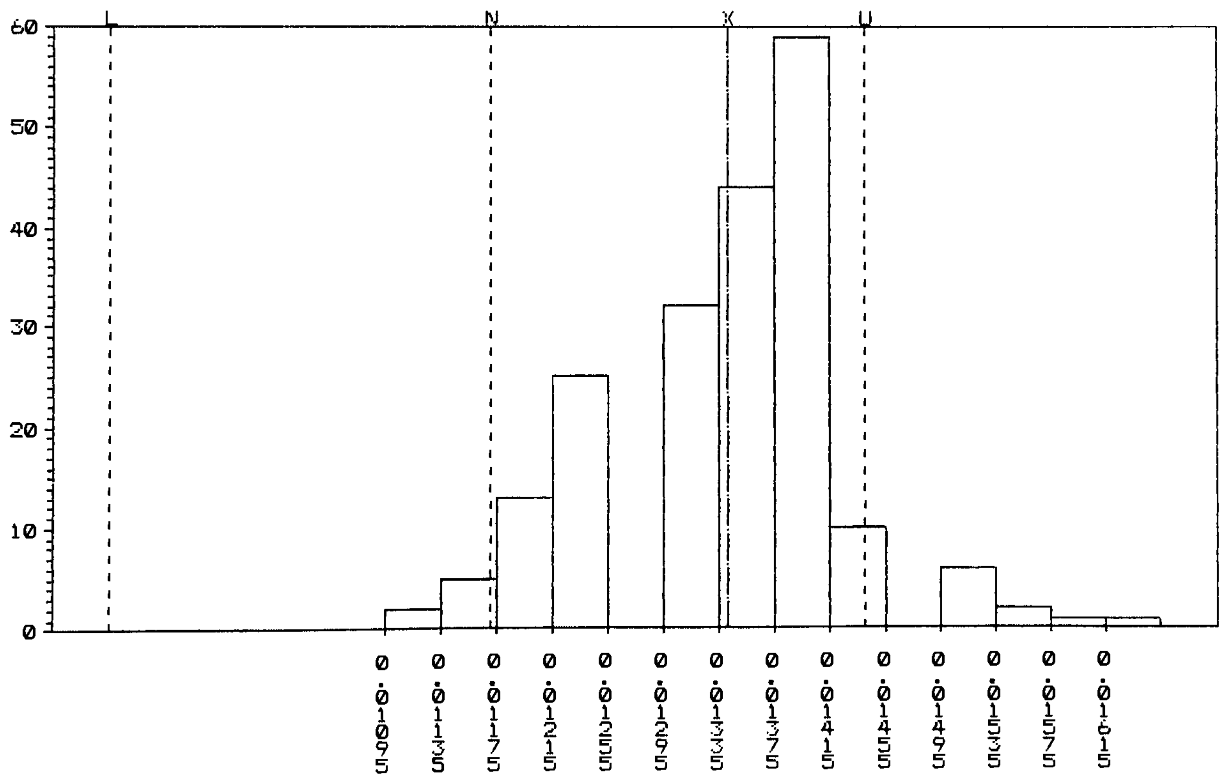
Final Test Ink - 0.90 Mag.

File	:90TENSE	Date:09-07-1990, 11:21:47	
Company	:Jamestown Container Corporation		
Plant	:Jamestown Container	Part name	:Hydrotense
Department	:Printing	Part number	:*
Machine	:Martin	Sample frequency	:All
Operation	:Thesis Data	Units	:Inches
Characteristic	:Final Test Ink - 0.90 Mag.		

Descriptive Statistics

All samples(n=4)		Interval - 0.00040
200 data points		lower boundary
Mean = 0.01341	Min. Value = 0.0110	Chi Squared= 80.014
Sigma Indiv= 0.00088	Max. Value = 0.0165	deg. free. - 7
Est. Sigma = 0.00070	Kurtosis = 0.618	Conf. Level= 95%
Coeff.Var. = 0.06574	Skewness = -0.052	Not Normal
Capability	Actual %	Upper Spec.- 0.01440
Using Sigma Indiv	Above Spec = 10.00	Nominal 0.01170
	Below Spec = 0.00	Lower Spec.- 0.00900
Cpk - 0.37	Out of Spec= 10.00	
Cp 1.02	Theoretical %	
Cr 0.98	Above Spec = 13.14	
Z upper 1.12	Below Spec = 0.00	
Z lower - 5.00	Out of Spec= 13.14	

Histogram/Capability



FILE: 90TENSE

DATE: 09-07-1990

Plant....................Jamestown Container
Department...............Printing
Machine..................Martin
Operation................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01275	.0010	.01250	.00050		.0125	.0125	.0125	.0135
2	.01362	.0015	.01350	.00063		.0130	.0135	.0135	.0145
3	.01325	.0005	.01325	.00029		.0130	.0135	.0135	.0130
4	.01350	.0015	.01375	.00071		.0125	.0135	.0140	.0140
5	.01300	.0015	.01275	.00071		.0140	.0125	.0130	.0125
6	.01300	.0025	.01325	.00108		.0130	.0115	.0135	.0140
7	.01312	.0020	.01325	.00085		.0130	.0120	.0135	.0140
8	.01325	.0015	.01325	.00087		.0125	.0140	.0125	.0140
9	.01275	.0015	.01275	.00065		.0125	.0120	.0135	.0130
10	.01262	.0025	.01250	.00111		.0130	.0115	.0120	.0140
11	.01262	.0020	.01225	.00095		.0120	.0120	.0125	.0140
12	.01325	.0030	.01350	.00126		.0135	.0115	.0135	.0145
13	.01300	.0015	.01325	.00071		.0135	.0120	.0135	.0130
14	.01287	.0015	.01300	.00063		.0130	.0120	.0130	.0135
15	.01237	.0035	.01200	.00170		.0110	.0110	.0130	.0145
16	.01375	.0005	.01375	.00029		.0135	.0140	.0140	.0135
17	.01300	.0010	.01300	.00058		.0125	.0125	.0135	.0135
18	.01312	.0025	.01300	.00103		.0120	.0130	.0130	.0145
19	.01287	.0025	.01300	.00103		.0115	.0130	.0140	.0130
20	.01287	.0010	.01275	.00048		.0125	.0125	.0135	.0130
21	.01312	.0015	.01300	.00075		.0125	.0125	.0135	.0140
22	.01462	.0010	.01475	.00048		.0150	.0140	.0145	.0150
23	.01462	.0020	.01475	.00085		.0150	.0135	.0145	.0155
24	.01387	.0005	.01400	.00025		.0135	.0140	.0140	.0140
25	.01400	.0020	.01400	.00082		.0150	.0140	.0130	.0140
26	.01450	.0020	.01400	.00100		.0140	.0160	.0140	.0140
27	.01475	.0025	.01425	.00119		.0140	.0140	.0145	.0165
28	.01400	.0015	.01375	.00071		.0150	.0135	.0140	.0135
29	.01337	.0020	.01375	.00095		.0135	.0120	.0140	.0140
30	.01375	.0010	.01400	.00050		.0140	.0140	.0130	.0140
31	.01225	.0015	.01225	.00065		.0130	.0115	.0125	.0120
32	.01312	.0010	.01325	.00048		.0130	.0135	.0135	.0125
33	.01400	.0010	.01400	.00041		.0135	.0140	.0140	.0145
34	.01375	.0005	.01375	.00029		.0135	.0135	.0140	.0140
35	.01437	.0010	.01425	.00048		.0140	.0140	.0145	.0150
36	.01375	.0005	.01375	.00029		.0140	.0140	.0135	.0135
37	.01337	.0005	.01350	.00025		.0135	.0135	.0130	.0135
38	.01387	.0030	.01375	.00125		.0125	.0135	.0155	.0140
39	.01262	.0010	.01275	.00048		.0125	.0120	.0130	.0130
40	.01262	.0005	.01250	.00025		.0125	.0125	.0130	.0125
41	.01312	.0020	.01325	.00085		.0140	.0120	.0130	.0135
42	.01325	.0010	.01300	.00050		.0130	.0130	.0130	.0140
43	.01387	.0005	.01400	.00025		.0140	.0140	.0135	.0140
44	.01387	.0005	.01400	.00025		.0140	.0140	.0135	.0140
45	.01387	.0005	.01400	.00025		.0140	.0140	.0135	.0140
46	.01362	.0010	.01375	.00048		.0140	.0140	.0130	.0135
47	.01362	.0010	.01375	.00048		.0130	.0140	.0140	.0135
48	.01350	.0015	.01375	.00071		.0125	.0140	.0140	.0135
49	.01400	.0010	.01400	.00041		.0135	.0140	.0145	.0140
50	.01287	.0020	.01275	.00085		.0125	.0120	.0130	.0140

Final Test Ink — 0.80 Mag

File :80TENSE Date:09-07-1990, 11:23:42
Company :Jamestown Container Corporation
Plant :Jamestown Container
Department :Printing
Machine :Martin
Operation :Thesis Data
Characteristic :Final Test Ink - 0.80 Mag.

Part name :Hydrotense
Part number :*
Sample frequency:All
Units :Inches

Descriptive Statistics

All samples(n=4)
200 data points
Mean = 0.01194
Sigma Indiv= 0.00105
Est. Sigma = 0.00078
Coeff.Var. = 0.08820

Capability
Using Sigma Indiv

Cpk = -0.05
Cp = 0.44
Cr 2.26
Z upper = -0.14
Z lower = 2.80

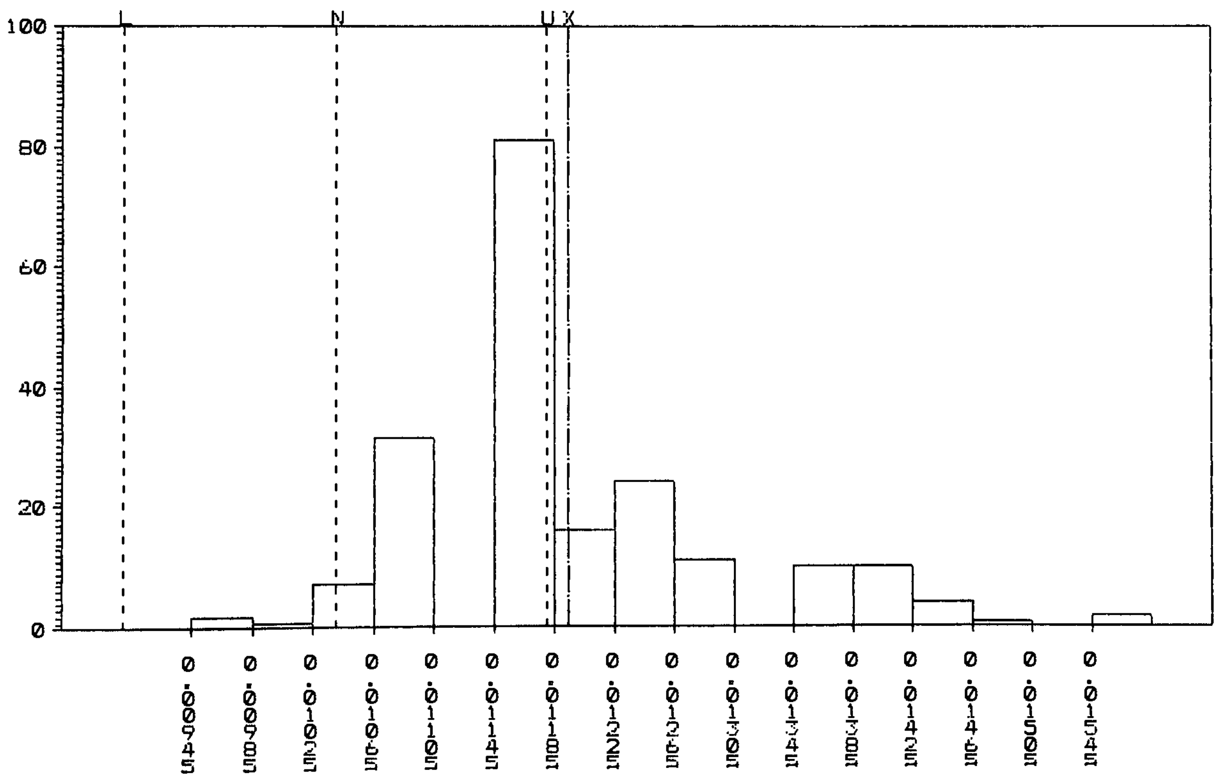
Min. Value = 0.0095
Max. Value = 0.0155
Kurtosis = 0.952
Skewness = 1.007

Actual %
Above Spec = 39.00
Below Spec = 0.00
Out of Spec= 39.00

Theoretical %
Above Spec = 55.47
Below Spec = 0.26
Out of Spec= 55.73

Interval = 0.00040
lower boundary
Chi Squared=174.961
deg. free. = 8
Conf. Level= 95%
Not Normal
Upper Spec.= 0.01180
Nominal = 0.01040
Lower Spec.= 0.00900

Histogram/Capability



FILE: 80TENSE DATE: 09-07-1990

Plant....................Jamestown Container
Department...............Printing
Machine..................Martin
Operation................Thesis Data

#	X-BAR	RANGE	MEDIAN	SIGMA	CAUSE	OBSERVATIONS			
1	.01162	.0015	.01150	.00063		.0115	.0110	.0115	.0125
2	.01187	.0020	.01175	.00085		.0120	.0110	.0115	.0130
3	.01275	.0020	.01300	.00096		.0135	.0125	.0135	.0115
4	.01225	.0015	.01225	.00087		.0115	.0130	.0130	.0115
5	.01187	.0015	.01200	.00075		.0125	.0115	.0125	.0110
6	.01200	.0010	.01200	.00058		.0115	.0115	.0125	.0125
7	.01150	.0010	.01150	.00041		.0115	.0110	.0115	.0120
8	.01150	.0010	.01150	.00041		.0110	.0115	.0115	.0120
9	.01087	.0010	.01075	.00048		.0105	.0110	.0115	.0105
10	.01212	.0010	.01225	.00048		.0125	.0115	.0125	.0120
11	.01112	.0010	.01125	.00048		.0110	.0105	.0115	.0115
12	.01125	.0010	.01100	.00050		.0110	.0110	.0110	.0120
13	.01187	.0015	.01200	.00075		.0115	.0110	.0125	.0125
14	.01212	.0010	.01225	.00048		.0120	.0125	.0125	.0115
15	.01162	.0015	.01150	.00075		.0120	.0110	.0110	.0125
16	.01162	.0015	.01150	.00063		.0110	.0115	.0115	.0125
17	.01175	.0025	.01175	.00119		.0105	.0110	.0125	.0130
18	.01150	.0000	.01150	.00000		.0115	.0115	.0115	.0115
19	.01162	.0010	.01175	.00048		.0120	.0110	.0115	.0120
20	.01237	.0015	.01250	.00063		.0115	.0130	.0125	.0125
21	.01075	.0015	.01075	.00065		.0100	.0105	.0115	.0110
22	.01350	.0025	.01325	.00108		.0130	.0125	.0135	.0150
23	.01300	.0025	.01325	.00122		.0140	.0125	.0115	.0140
24	.01262	.0030	.01225	.00131		.0145	.0125	.0115	.0120
25	.01375	.0040	.01400	.00166		.0140	.0115	.0155	.0140
26	.01262	.0030	.01275	.00160		.0140	.0115	.0140	.0110
27	.01275	.0025	.01275	.00119		.0135	.0120	.0115	.0140
28	.01300	.0025	.01325	.00108		.0135	.0130	.0140	.0115
29	.01212	.0035	.01150	.00160		.0145	.0110	.0115	.0115
30	.01275	.0025	.01275	.00119		.0120	.0115	.0135	.0140
31	.01100	.0010	.01100	.00041		.0115	.0105	.0110	.0110
32	.01150	.0010	.01150	.00041		.0115	.0115	.0110	.0120
33	.01162	.0005	.01150	.00025		.0115	.0115	.0115	.0120
34	.01225	.0015	.01225	.00087		.0130	.0115	.0130	.0115
35	.01325	.0030	.01350	.00126		.0135	.0115	.0135	.0145
36	.01150	.0000	.01150	.00000		.0115	.0115	.0115	.0115
37	.01125	.0005	.01125	.00029		.0110	.0110	.0115	.0115
38	.01300	.0030	.01300	.00129		.0135	.0125	.0145	.0115
39	.01037	.0020	.01025	.00103		.0110	.0095	.0115	.0095
40	.01150	.0000	.01150	.00000		.0115	.0115	.0115	.0115
41	.01112	.0005	.01100	.00025		.0110	.0115	.0110	.0110
42	.01125	.0010	.01150	.00050		.0105	.0115	.0115	.0115
43	.01262	.0025	.01250	.00131		.0140	.0115	.0135	.0115
44	.01137	.0005	.01150	.00025		.0110	.0115	.0115	.0115
45	.01237	.0045	.01150	.00210		.0115	.0110	.0155	.0115
46	.01212	.0015	.01200	.00075		.0125	.0115	.0130	.0115
47	.01200	.0020	.01200	.00091		.0110	.0130	.0115	.0125
48	.01150	.0000	.01150	.00000		.0115	.0115	.0115	.0115
49	.01175	.0005	.01175	.00029		.0115	.0120	.0120	.0115
50	.01175	.0010	.01150	.00050		.0115	.0115	.0125	.0115

APPENDIX E

Cost Savings
Preliminary Test Ink vs. Final Test Ink

Month	Actual Usage In Pounds	Preliminary Test Ink Cost/Lb.	Final Test Cost/Lb.
October 1988	4,525.00	$1.04	$1.69
November 1988	4,750.00		
December 1988	4,930.00		
January 1989	5,380.00		
Average Monthly Usage -	4,896.25		
Yearly Average In Pounds -	58,755.00		
Average Ink Cost/Year		$61,105.20	$99,295.95
Annual savings if the Preliminary Ink is substituted for the Final Test Ink =		$38,295.95	

NOTE: All figures are based on the ink color used during this research - GCMI 31-Blue

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